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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

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ENGINEERS' CONTRACTS AND SPECIFICATIONS FROM A CONTRACTOR'S POINT OF VIEW.

BY JAMES W. ROLLINS, JR., MEMBER OF BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, Feb. 20, 1907.]

ACCORDING to Mr. John Cassan Wait, an authority on engineering contracts, the essential elements of any contract are as follows:

First. Two parties with capacity to contract.

Second. A lawful consideration.

Third. A lawful subject matter.

Fourth. Mutuality: a mutual assent, a mutual understanding, a meeting of the minds of the parties.

This fourth element is the one which most appeals to me to-night, and to which I shall devote most of my time.

A mutual understanding, that is, each of the parties to the contract is to know and understand as nearly as possible just what is meant for each to do, and to this end the contract must be explicit in all its terms.

It is supposed as a basis of argument that both of the parties are fairly disposed towards one another, neither to try to gain an advantage, and that all acts are as *between man and man.*

A contractor must base his figures on definite information, or else make some wild bid, the degree of wildness being in accord with the risks to be run. On some contracts this element of uncertainty must be large, and the writer believes this to be the only class of work properly done on a percentage (or cost plus) basis. But also in very many other contracts there are

many uncertainties injected; some dependent on the wording of certain clauses, from which the contractor's only hope of salvation is the fair-mindedness of the engineers; and here the man, knowing the engineer and his way of handling work, has the advantage over the stranger.

For instance, quoting from an existing contract, — " Excavations shall be made of dimensions indicated upon the plans, where dimensions are given, *except as otherwise directed.*"

" Piles shall be driven not below elevation 102, and shall be cut off at these levels unless *otherwise directed.*"

In the first case quoted, plans showed excavation to -28, and then comes in the " otherwise directed " clause by which excavation could be made to -50 if desired, at no extra price to contractor.

Under the pile clause, they may be cut off anywhere.

Referring to another contract — for a dam — " if excavation is required below a certain grade, a special price is to be paid for such work."

Which of these clauses do you think the most fair, and can you suggest any reason for putting such uncertainties into a contract, without provision for a just and proper payment for the work done?

The very customary clause in a contract, which makes the chief engineer the sole judge of everything, the quality of work, the amount done, and the value of it, appears to us to be a most unjust clause, and one entirely out of the spirit of mutuality which has been referred to. The need of an arbitrator does not come until parties in interest have disagreed, and then under this clause one of them settles it " for good and all." It takes a true and good man to be entirely just in settling a row in which he has been a participant, and may have even been " knocked out " in the first round. It is not uncommon to hear of engineers " who will get even with contractors."

A more just and proper clause is such a one as this, which is now quite common with engineers, and is a standard clause in architects' contracts:

" Should any dispute arise concerning the true construction of the plans or drawings and specifications hereinafter mentioned, or any part of either, the same shall be decided by the said engineers, and their decision shall be final; but should any other difference arise between the parties of the first and second parts, the same shall be submitted to the arbitration of two competent and disinterested persons, one to be named by the party of the first part, and the other by the party of the second part, which

two in case they cannot agree may choose an umpire; and the decision of the arbitrator, or the umpire, shall be binding and conclusive on all the parties hereto.

"It is on this same ground of public policy, that agreements by contractors to abide the decision of the engineer as final and conclusive without recourse to courts of law or equity have been declared not binding — illegal and void. The courts have held that the Government guarantees to every man the protection of the courts and their assistance and that no man can enter into a contract that shall deny him this privilege and right."*

On the mutuality basis, the absolute disclaimer of any responsibility for the accuracy of borings seems unjust. Many of our large water jobs give us extensive and detailed plans of borings, and contractors must necessarily base their figures on them. If these borings prove to be wrong, and the contractor suffers thereby, why should not this be borne by the owners? It is not a contingency figured on by the contractor, and in all faith and justice he should not suffer. He has to take chances on the winds and the floods, the frosts and the thaws, the acts of God and the perversity of man, of quicksand and other classes of excavation; so why should be added to all these the errors of "borists," and they make many?

When we drive piles through 20 ft. of solid rock, or 50 ft. through "sand and gravel, very hard," and have figured on short piles, we have a spirit of "kick" in us, and think someone should pay the price. You engineers all say, "We gave you the results of the borings out of the spirit of our hearts to help you, and we thought them correct; so you shouldn't look a gift horse in the mouth and complain, but should take your medicine." Here the "mutuality" comes in; the basis of the contract was wrong. It seems to me it is one of the items of common misunderstanding, which might be eliminated.

Every contract to-day affords ample protection against unjust claims for extra work; most engineers check up all costs of such, and by the contract, bills for same must be rendered monthly; so how is it possible for any great "graft" to come in with such claims?

Clauses in contracts which in any way give the engineer control over the methods to be used to do the work, or those which throw the responsibility of the work designed by the engineer on to the contractor, are great sources of trouble. This means divided responsibility, and this, as sure as fate,

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* Wait's Engineering and Architectural Jurisprudence, page 76.

trouble; for no two men, especially a contractor and an engineer, can exactly agree upon methods of doing work.

We are, to-day, at work on structures, every detail of which was designed by engineers; they have reserved the right to tell us in detail exactly how to do everything connected with it; and on the end of the contract clause are the words, "*the contractor shall assume all responsibilities in the work, and for the stability of the structure.*"

What do you think of that? But one thought can come to you, and that is, we must be idiots to sign any such contract. In a great measure we are idiots, but we have to run chances other than acts of God, etc., and that is, I am glad to say, one chance we rarely lose, that the engineers are fair and honorable men in settling matters of this kind.

You all know of the trouble from such a clause in the Charlestown Dry Dock, where the contractor was to submit a plan for cofferdam satisfactory to the engineer. He submitted one, of the most common and efficient type, but it was not approved. After many delays a plan was approved, the dam built and *failed*, and there are now pending claims of hundreds of thousands of dollars against the Government, on account of this failure.

Personally, the writer fails to see why any engineer wants to assume the responsibilities of others, and, where his clients are protected by suitable bonds, why he doesn't let the contractor go ahead and make his own plans and work out his own salvation, or damnation, as he will.

A clause from a Boston Transit Commission contract bears on this subject:

> "But neither the Commission, nor any member of it, nor the engineer, etc., shall have any control or direction over the progress of the work, nor any control or superintendence over the apparatus, ways, works, machinery or plant; the sole responsibility for the proper handling of which, as well as for the safe and proper conduct of the work, resting solely with the *contractor.*"

Inasmuch as this commission's work was done under very expensive buildings and the city streets, where great trouble, loss of property and life, were possible, it seems to me that the commission showed its good sense by keeping clear of the "ways and means," and the temporary work, and letting the contractor do the work his own way and assume the responsibility.

The only time we came near trouble in the Charles River

cofferdams was due to the divided responsibility, we thinking the inspector was on to his job, and the dam engineers thinking it was our cofferdam, so neither kept track of a certain section and left some very necessary bolts out.

On this job where we are under $150 000 bonds and the commission has $60 000 in reserved percentage, it wants us to build a temporary structure on its design and at our risk. Inasmuch as this structure has a factor of safety of about twelve, we do not feel troubled at taking this responsibility, but still we object strongly to the principle.

Another clause in many contracts: That the engineers may shut down the work at any time and for any reason and the contractor has no redress. This clause must have had its origin in old railroad construction, where the question of right of way, or of alignment was always uncertain, and it has been perpetuated to-day to our great sorrow and many times our loss. Here again the mutuality comes in, the contract was let in good faith, with no idea of any delays for anything.

To insure the completion "on time" the lawyers — I don't think the engineers ever coined any such expressions — meekly say, "Time is of the essence of this contract, and you shall pay $100 a day, not as a penalty, but as liquidated damages." We know what liquids are and what damages may be, but we haven't been able to find the difference to our pocketbooks between "liquidated damages" and a "penalty."

Hence the proposition: We must finish on time or pay $100 a day, but the commissioners can hold us up for any length of time and pay us nothing for the loss to us for this delay. We build special plant to do the work, get men trained to do the work properly and well; then comes the order to stop, shut down the plant and discharge the men. The plant cannot be moved, but must stay idle, new men must be trained over again; if work is done on a rising market, if labor demands more pay, we pay it, and all this loss comes on the contractor. Why should it? We didn't figure on it. It is a contingency unseen, and in all justice payments should be made on the *mutual understanding basis.*

Not content with the general obnoxious and unjust conditions mentioned, which are very common in contracts, often special provisions are made, which put most extraordinary powers in the hands of the engineers, and as they are hastily read over by the contractor, do not mean much. For example:

"The said contractors hereby declare and agree that they shall be accountable for the full performance of this contract, and by the signing hereof admit that the said plans, elevations, sections, specifications and parts before referred to are sufficient for their intended purpose of doing the said work, and that the work can be successfully executed in accordance therewith without any additional or extra work other than that set forth thereby or necessarily inferred to be done from the general nature and tendency of the plans, drawings and specifications aforesaid upon a fair and liberal construction thereof."

This innocent clause cost us on one contract $10 000. We took a contract to rebuild two abutments and one pier for a river bridge. The plans, not very complete, showed the new abutments to be about 18 in. clear behind the old work, which had to remain in place until new work was built. These abutments were 36 ft. high; and when excavation got down to water level it was found that the old work was thicker than the plan showed, and left no room to put in cofferdam between it and the new work. It cost $10 000 to get the lower 4 ft. of these foundations, owing to the inability of making cofferdams tight.

We protested to engineer on first abutment, but to no avail, asked that other abutment be "fudged" back 2 ft., an easy matter, but no change was allowed. Work was finally completed and demand made for extra pay for work, on account of errors in plans; was not granted, and was then left to be arbitrated as contract provided, the chief engineer meanwhile *insisting* that his company or his office was not at fault, or liable; and this clause was then brought out by our own lawyers, and we were advised that we had assumed all responsibility in the matter and had agreed that the plans were sufficient to do the work called for, with no extras.

Later on this same contract we deposited concrete under water, and after a month it proved worthless, and examination showed that the river water was polluted to such an extent as to destroy the cement: to do the work then required a cofferdam to be driven for pier in the middle of the river, the water pumped out and masonry substituted for concrete.

Again was this clause brought to our attention and our counsel advised it was very doubtful whether we could recover in court, even though the contract in a way required an impossibility.

It is a general impression among engineers that clauses requiring impossibilities are null and void and that a court would not recognize them; but the law on the case is very

deficient and the cases tried in this country very limited. These cases always go back to a London bridge case, Thorn *v.* Mayor of London, which was as follows:

"Defendants being about to erect a bridge an engineer prepared for them, at their request, plans and specifications both of the bridge and of the mode in which it was to be constructed.

"The plaintiff on the faith of these plans and specifications and without any independent inquiry whether the work could be done as specified, entered into contract with the defendants to do it in accordance with the terms of the plans and specifications. After the plaintiff had incurred great expense it was found that the work could not be executed in the manner specified. The plaintiff sued the defendant on the ground of an implied warranty by them that the work could be executed in the manner described in the plans and specifications.

"Held that no such warranty could be implied.

"This bridge, Blackfriars Bridge, was built about 1864 across the Thames. By a clause 54 the contractor was to satisfy himself as to the nature of the ground through which the foundations were to be carried; it was stated that all the information given on this subject was believed to be correct, but was not guaranteed.

"The caissons built according to plans and specifications were not strong enough to resist the pressure, so that a large part of the work had to be done at low or half tide, thus causing great delay and additional cost.

"The Court seems to lay the blame on the contractors on the ground that it was their duty to examine for themselves the question whether the method of the engineer for the city was right or not.

"This case went up finally to the House of Lords.

"The Lord Chancellor (Cairus) said, in giving his opinion, 'Mr. Corbitt (engineer for the city) considered that the bridge could be built in a manner somewhat, if not altogether, modified by the use of caissons in place of cofferdams, and the specifications and drawings were made on that footing.'"

[So it would seem that the engineer for the city made an experiment and the contractor paid for it.]

There was a provision in the contract for payment for extra work.

Only the upper part of caissons had to be abandoned by reason of the great pressure, which necessitated doing of the upper part of the work at low or half tide when it could be done.

All the judges (in the House of Lords) concurred; and they all seem to agree that it was the contractor's duty before making the contract to satisfy himself that the work could be done efficiently under the plans and specifications furnished by the city; all engineers, they say, are liable to error.

[Why not the engineer for the city as well as the contractors?]

This case has been much commented on both in England and in the United States.

The judgment in the House of Lords, however, leaves it an open question whether the plaintiff (contractor), assuming the extra work not to have been extra work of the kind contemplated by the contract itself and to be paid for under it, might not have recovered for it as a *quantum meruit* (*i.e.*, as per services rendered for the benefit and at the request of the plaintiff though not under an express contract).

A Recent Opinion of the Court on the Question of Executing an Impossibility.

The Court in the opinion stated that the delay was one due to the contractor's error of judgment, and that there appeared to be no ground upon which he could ask to be excused from the consequences of his own mistake. The Court cited with approval the rule expressed in the case of Chicago, etc., Railway Company *v.* Hoyt (149 U. S., p. 14), which is as follows:

"There can be no question that a party may, by an absolute contract, bind himself or itself to perform things which subsequently become impossible, or pay damages for the non-performance, and such construction is to be put on an unqualified undertaking where the event which caused the impossibility might have been anticipated and guarded against in the contract, or where the impossibility arises from the act or default of the promisor. But where the event is of such a character that it cannot be reasonably supposed to have been in the contemplation of the contracting parties when the contract was made, they will not be held bound by general words which, though large enough to include, were not used with reference to the possibility of the particular contingency which afterwards happens."

In another case of work we did, this application of an impossibility clause came in as follows:

Plans showed 6 in. hard pine sheeting driven to a depth of − 20, and specifications said simply, "Sheet piling shall be driven as shown on plans"; and no borings or samples were shown, and no mention made of material or the possibility of hard driving, though the ground showed sand.

Before we got ready to do our work other contractors had driven sheeting of same kind for a trench, and their work, though done under much easier conditions (*i.e.*, with sheeting driven only a little ahead of excavation in trench), showed the timber to be seriously crippled by the gravel stratum into which

it was driven. Our line of sheeting was to act as a permanent bulkhead, and to be of any value should be put into place without crippling. We tried all sorts of ways to get the sticks down, with a jet and otherwise, and finally gave up the attempt on the assurance of the engineer in charge that, in his opinion, we could not *drive it* in a way satisfactory to him.

We took up the "impossibility plea" and were gently advised by the owners that in the opinion of their lawyers we agreed to drive that sheeting as shown on plan, and that we must do this, even though the material was rock and we had to bore holes to put the sheeting into.

We finally dredged the gravel out, drove our sheeting, back-filled it, finished the work, the company paying us, I think, cost of dredging.

But these cases put all the burden of unforeseen things on the poor contractor, and when trouble comes, the engineers refer the matter to the lawyers and they interpret the law, not by right or justice, but the strict legal meaning of the contract, and I venture to say that not a single contract is made to-day on large works, which does not give the engineer power enough to put the contractor into bankruptcy by such clauses as I have been quoting. All this is unnecessary. Every contract has a provision for extra work and for the filing of all claims for damages, change of plans, etc., with engineer once a month, and the right of engineer to see all papers connected with these claims. They cannot be collected by demand of contractor, but only at last resort by a court of law, which in our free country is the court of last resort to all injured souls. So why should not contracts be made which give the contractor some rights to a settlement other than by the man he cannot agree with, by some disinterested person who can do justice, having some regard to the old principle of man-to-man settlement?

"Every unnecessary or unfair clause in a specification has its part in limiting competition, and in lowering the standard of honesty among contractors. A clause that may be used as a club can be avoided in one of two ways, either by not bidding on work governed by the clause, or by using 'graft' to insure that it shall be a dead letter."

Many contracts to-day show the improvements which we wish to become more general, and eliminate the clause which makes the engineer the final judge of all things, substituting settlement of disputes by arbitration. This is a great step

forward, and we trust that the other few clauses which make trouble, when trouble comes, may be eliminated.

The courts now lean towards the "intent" of the parties making the contract, the "mutual understanding," between the contracting parties. This means that the contractor shall do what the plans and specifications call for in a fair and just interpretation and under the conditions which at the time of making the contract seem to be most probable, and such understandings must bar out the particularly objectionable clauses as follows:

First. Disclaiming responsibility for soundings or other information as to the character of the work.

Second. The insertion of clauses which make any contractor's estimates worthless by adding, "or as otherwise directed."

Third. Making the contractor responsible for work for which engineers make the plans or require their approval to any made by contractor, and where engineers reserve the right to entirely control the manner and means of construction.

Fourth. Holding contractor responsible for work which has passed inspection or has been done under direction of engineer, or his agent, or inspector, unless fraud can be proved.

Fifth. Making the engineer the sole referee in settling all claims.

Sixth. The right to stop work, or any part of it, if for the interests of the company so to do, without allowing the contractor anything for the loss such action might bring to him.

When these clauses are eliminated and others substituted which give the contractor the benefit of the "intent" of the contract, and which will insure a settlement on that basis by disinterested parties, then comes the day of freedom for contractors.

I commend to you the *Engineering News*, on whose editorial staff is some writer on this subject, with whose sentiments I most heartily agree. He says:

"We wonder whether, if contractors were treated with something like a square deal in letting contracts, there might not be less temptation to graft in their execution."

The following comments on two specification clauses relating to extra work, made by correspondents in *Engineering News*, are of interest:

"We have had occasion to criticise certain specification clauses relating to payment for extra work, because of their failure to define what was meant by the expression 'actual cost plus 15 per cent.' The following clause from a recent sewer

specification is, in this respect, the most definite of its kind that we have seen:

" 'Extra work ordered in writing by the board or the engineer will be paid for at the reasonable and actual cost of the same plus 15 per cent. for profit, superintendence and general expenses. The said cost of the extra work shall include all fuel, materials and labor furnished by the contractor, but it shall not include office expenses, general superintendence, salaries, use of tools or machinery or other general expenses.'

"There seems to be some doubt whether, under this clause, the cost of 'bossing' the job is included or not. General superintendence is specifically excluded, but nothing is said as to foremen, unless we take the word 'salaries' to include all men paid by the week in distinction from men paid by the day. Foremanship may itself run from 5 per cent. to 15 per cent. of the total cost of small engineering works, so that it is important to include it specifically in the items of 'actual cost' to which the 15 per cent. is to be added. It is immaterial whether the foremen in charge of separate gangs of men are paid by the day, by the week or by the month, hence the word 'salaries' if used at all in a specification should not be made to include the foremen who are bosses of individual gangs.

"Now a word as to the specified percentage to be added for profits. It has been the experience of a well-known contractor with whose records we are familiar, that on sewer work the general 'expenses' (exclusive of foremanship) seldom amount to less than about 7 per cent. of the total cost, and that the wages (or salaries) of bosses will average another 10 per cent.

"The insurance of sewer laborers amounts to several per cent. of the payroll. Indeed, there are cities where the soil is so treacherous that surety companies fix premium rates that are practically prohibitive. One cave-in may wipe out several thousand dollars' worth of premiums, by causing the death of a man.

"We see, therefore, that there are conditions under which 15 per cent. added for profits is in reality 15 per cent. added for expenses that are as actual as the weekly payroll. Each piece of work must be considered by itself in specifying the percentage for profits, but in all cases the cost of foremen should be included.

"Where an expensive plant is likely to be required, it may be desirable to specify a certain percentage of the first cost of the plant to be allowed for 'plant rental,' and considering this 'plant rental' as an item of the 'actual cost.'

"It will be noted that fuel is included as an item of 'actual cost.' This should always be done, as fuel is often an important item, and its cost is readily ascertainable." * * * *

"The same specification from which the foregoing clause was abstracted contains the following:

" 'The Commission reserves the right to increase or decrease the work, or to stop the work, wholly or in part, at any time. Nor will the Commission be liable for any loss or damage to the contractor because of any stoppage of the work.'

" A number of complaints from contractors contemplating bidding upon this work seem to justify giving space to this clause, in spite of the fact that similar clauses have been previously discussed in the columns of this Journal. It appears not to have occurred to the author of this specification that the element of time is a factor of importance to a contractor, or that the amount of work to be done affects the unit cost, or that there is any unfairness in a specification that permits one party of a contract to escape from the implied obligations while rigidly holding the other party to performance. Nor does it seem to have been regarded as possible that some contractors might hesitate to buy a plant or part of a plant to do work which may be shut down before the plant has been in operation long enough to pay the freight from the factory. Every clause like this brings its own punishment either by causing only a reckless class of contractors to bid or by causing conservative contractors to bid an exceedingly high price to cover risks. There are internal evidences of lawyer authorship of these specifications; and it is not improbable that if an engineer ever had a hand in the original draft, he has been forced to see all semblance of fairness wiped out by a few legal, but foolish, pen strokes; for it is an economic folly to attempt to play fast and loose with intelligent and reliable contracting firms.

" A clause governing the excavation of rock for a dam site has some interesting and self-contradictory features to which attention may well be called. It reads as follows:

" ' In this excavation the kind of explosives used, the amount of the charges, the depth and direction of the holes and the entire process of the work shall be under the control of the engineer, the object being to do the work in such a manner as to avoid fissures in the remaining rock.

" ' If at any place the contractor shall excavate, damage or shatter the solid bed rock beyond the lines given by the engineer to be excavated, and it is necessary to replace the solid rock by masonry, then the contractor shall supply such masonry free of cost to the company.'

" In the first sentence the engineer usurps one of the most important functions of the contractor by asserting that ' the entire process will be under the control of the engineer '; and in the next sentence he seeks to escape the responsibility that morally and legally falls upon the shoulders of any one who assumes entire control of any method or process of construction. We have here an excellent example of the lax ideas that prevail as to what constitutes a free contractor and a servant. A contractor cannot legally be made both. If it is desired to hold the contractor to a removal of all rock shattered beyond the neat lines, then the engineer must carefully avoid acting as a master or ' boss ' in directing just how the drilling and blasting shall be done. If, on the other hand, the engineer believes that he, himself, is a more competent blaster than any contractor is likely to be, let him manfully assume the responsibility for his own work; and he may as well assume it, for he cannot legally escape it in case of a law suit.

"The fact is that if the engineer does really possess an intimate knowledge of the proper methods of doing work, he usually is specific and not vague. He does not hide behind such generalities as are contained in the first sentence in the clause under discussion, but he says: 'Such and such a kind of explosive shall be used, and so and so many pounds of the explosive shall be the maximum charge per foot of drill hole, and no drill hole shall extend more than so and so many inches beyond the neat lines of the excavation, and drill holes shall be spaced so and so.' Such a specification shows at least that a study of the problem has been made by the engineer, and that he is prepared to stand by something definite.

"On the other hand, if the engineer cannot define what shall be done, for one reason or another, he had better take one of two courses: (1) Leaving the means and methods entirely to the contractor who is held strictly responsible for certain results; or (2) assuming entire charge of means and methods and specifically releasing the contractor from responsibility for results. Any attempt to follow both these courses is obviously unjust, and, what is equally to the point, will be upheld by no court.

"We have assumed, up to this point, that the contractor has no redress, but to any one familiar with the law of contracts, it is well known that an unreasonable interpretation of such clause as the one under discussion will render the employers of the engineer liable for damages; for, carrying the clause to an extreme, it would be possible for the engineer to compel practical abandonment of the work during the summer months and the use of doubly large forces during the winter months, a procedure which would ruin almost any contractor. Yet this procedure would be literally in accord with the wording of the clause which empowers an engineer to designate the time and place of attack and the size of the working force. No court will uphold a contract under which one man, at his option, may ruin another. The extent to which an engineer may legally direct the forces of a contractor will depend upon the reasonableness of the engineer's rulings. To prove or disprove the reasonableness of any ruling is a matter of evidence as to the facts and of expert evidence as to common practice. The cost of a law suit and doubt as to the outcome have deterred many a contractor from bringing suit; but the fact remains that, whenever an engineer ceases to be fair and reasonable in his interpretation of such clauses as the one under discussion, he runs the risk of forcing his employers to defend a law suit which will be expensive to them no matter what the final decision may be."

The following quotations are taken from a very interesting paper by W. F. Dennis, entitled "Uniformity of Requirements and Clearness of Specifications in Agreements for the Graduation of Railroads," to be read at a meeting of the American Society of Civil Engineers to be held March 6, 1907, and printed in the January, 1907, Proceedings of that Society, page 39 *et seq.*

"Agreements generally contain amplified stipulations that construction must be maintained by the contractor until the final acceptance by the engineer. This seems fair enough on its face, but the customary wording does not make equitable distinctions. It is easy enough to see that if the contractor, in such an act as transporting material to the work, suffers loss or damage of that material before it is put into the structure, the company has equitably nothing to do with the damage.

"Further, it is not unreasonable that a structure, such as a building, completed in advance of other work, all subject to acceptance at one time, should be insured by the contractor. The question becomes somewhat involved in the instance of, say, trestle-work which has been finally completed, in the event of destruction from a cause, not the fault of the contractor, before acceptance of the work as a whole; for railroad embankments washed away by water; for the destruction of masonry already laid according to specifications. If the contractor places the material where he is directed, no stretch of imagination could make it fair for him to be responsible for destruction by the elements when he has no control over the selection of the location or plan.

"As illustrative of the way in which equities are destroyed by such clauses, the writer recalls a case where a retaining wall which was too light fell down when the embankment was placed against it. The wall was rebuilt, payment for it denied, and the contractor sued. He established the fact that the wall fell because of improper design, and that the workmanship was according to contract. He lost on the ground that his contract was not only to build, but to maintain until acceptance, and his remedy would have been to have notified the engineer that the design was insufficient and to have made formal protest to building it.

"The writer recalls a personal experience in building a 30-ft. arch. This arch was built on a cemented gravel foundation which was perfectly satisfactory to the engineer and would have been all right ninety-nine times out of a hundred. The side walls and four cross walls were carried well down, and the bottom was paved with heavy stone on edge, well laid. The whole work was built under continuous inspection, and the destruction hereafter referred to revealed no fault of workmanship or material.

"This arch was accepted on a Friday. In the meantime the fill had been completed for part of its width over the arch, damming the small valley except for the arch opening of about 25 by 30 ft. On the following Tuesday, a cloudburst occurred, and the arch ran full and discharged as a pipe. The paving was dug out by the current, then the gravel was eroded, the side-walls fell in, and the disrupted structure was spread over three acres of ground.

"The first question asked by the management was whether or not the contractor was responsible under the 'insurance clauses.' This was disposed of by the technicality that the arch

had actually been accepted a few days before. Suppose the accepting engineer had been delayed on Friday and calculated to get there on Tuesday, instead; then a strictly technical construction of the agreement would have involved the contractor in replacing 3 000 yd. of masonry at his own expense. What had the contractor done, or not done, that could have made any real change in the equity of his position?

"According to the teaching of the case first cited, the contractor's legal duty was to have formally notified the company of what was not a fact, that the foundation was bad, and to have refused to build on the accepted foundation, except under protest. It seems to the writer that the simplest investigation of how unfairly these clauses can work out is amply sufficient to show the necessity of eliminating most of them and very carefully restricting the others.

. . . .

"Contractor to do the work where and when the engineer shall direct, whether the procedure is, or is not, a reasonable one in economical organization, and whether or not the procedure is fair.

"Where the company is in default from any cause, the expense shall be borne by the contractor, his relief is in extension of time, provided he gives notice and the engineer considers the point well taken.

"The contractor shall equip his work with such forces and appliances as the engineer shall direct. In case he does not, the company holds the right to employ the force and charge the expense; to annul the contract in whole or in part; to seize the contractor's plant; and to withhold any unpaid sums of money which may then be due. The contractor's employees are subject to discharge by order of the engineer. A reservation of 10 per cent. is withheld from the contractor's payments in addition to withholding, by custom, another part at the discretion of the subordinate engineer. The company, of its own motion, without default on the part of the contractor, holds the right to terminate the contract at any time, to suspend the work, to hold the contractor to resume, with stipulated denial of the contractor's right, not alone to damage, but even for recovery of expense. The contractor must obey all orders of the engineer and accept his determination as final, at a time when the engineer holds the relation of an employee and agent of the company; the contractor knowing at times that the engineer has no detailed knowledge of the work, and that the information which he certifies as his final judgment is, in fact, the work of an assistant, with whom he may not be even personally acquainted.

"Requirement that the company shall have the right to save itself in case of claims against the contractors; to make an *ex parte* examination, to settle the controversy and charge the contractor with the award and such expense as the company shall set, without consultation with the contractor, and without his acceptance. Requirement that the contractor shall exhibit complete receipts, showing that all accounts have been paid.

Requirement that the contractor shall save the company harmless from every matter growing out of the construction.

"Requirement that, before the contractor can get final payment for matters not in dispute, he shall accept the engineer's estimate as a total and release each and every matter and sign in full settlement, with a more drastic wording in some contracts; that the contractor shall have accepted the final, as handed out by the engineer, before the company shall have incurred any indebtedness to the contractor.

"Requirement that, after the contractor shall have done work which is satisfactory to the inspector appointed for it, the work may still be condemned and required to be done over.

"The stipulation in favor of the contractor is, that he shall have the right to accept without protest the sum of money the engineer shall say is due him.

"It is safe to say that in no other business relation between men are such one-sided agreements customary; in no other relation is a man conceived to be clothed, by reason of a written instrument, in a mantle of infallibility, as is the engineer in customary railroad contracts. In political matters, some thinkers hold that an intelligent despot can give the most efficient government; so, in the case of the engineer, granting an untrammeled, industrious and able man, subjecting the contract to his exclusive decision may work out as the best arrangement all around. As far as the writer's observation goes, the average and general result is good, without much genuine offset; but every now and then there is an instance of gross tyranny and outrageous wrong under these powers. The delays, safeguards and forms appropriate for a peaceful civilization would paralyze an active army. Railroad contract work requires somewhat of the army's autocratic directness of control, but the control should be within well-defined and reasonable lines.

"The objection in a practical sense, however, comes, not so much from arbitrary or unfair use of the engineer's power, but from his carrying out, or being forced into carrying out, requirements which are too broad or are unreasonable, which he may have thoughtlessly included in his agreement, put there from mere copying of precedent, or at the suggestion of a legal department which considers only its side of the case. Ordinarily, these clauses are unnecessary. In spite of them, most engineers have to and do make fair adjustments, and settlement for the majority of work goes through with mutual satisfaction. With these clauses too strongly drawn, the engineer, in spite of a personal desire to be fair, may be forced by his company into an opposite policy, in accordance with the stipulations of the contract. In no class of cases is there greater real damage done than when organized work is suspended or stopped.

"In the old days, when contractors' equipment was carts, scrapers and stock, the suspension of work was a serious blow. At the present time the organization and plant for work is multiplied many times more than the requirements of twenty years ago. The expense, effort and time sunk in organizing,

very often with special plant, has only a partial relation to the work which may be performed at a particular date. It is a general expense to prorate over all of it. Any suspension or stoppage cuts off the profitable part of the work, and where no compensation is made for the stoppage, the contractor is in effect robbed, whether it be by agreement or not, presuming that the contract was profitable in itself.

"It must be further considered that the contractor, in making agreement for a given piece of work, has taken the risk, and if it can be shown that the uncompleted work would have been profitable, upon suspension of this work, he is legally and fairly entitled to that profit, subject to such offset as would be made by an earlier release of services. The no-damage clause offsets this or any other claim.

"As the writer understands the obligation of contracts, in matters of measurement, classification, workmanship, meaning and application of specifications, and the like, which have to be decided by an expert, and for which the engineer is nominated by agreement as such an expert, his finding and decision will be held final in the absence of fraud. All other matters are at least open to court review. Therefore, a clear, fair contract interpreted by the engineer has a better chance to be upheld in its final than one which is unfair and extravagant in its stipulations in favor of the company. The time has about come for the companies to be willing to assume the risk of their own acts and plans, and not to saddle these risks further upon contractors.

"In conclusion, the writer would say that the main thought in this whole discussion is: That a contractor and a company enter into an agreement for mutual benefit. Every matter not clear, subject to whim and opinion in its working out, unfair in its intent, or in the nature of a 'strangle hold,' is unfair to one side and reacts upon the other, and that the business of both parties is best served by a fair agreement."

Specifications.

The troubles arising on account of specifications are due about equally to the text as written and to the interpretation of the text when written.

Engineering is an exact science, and a specification must be explicit and cannot use the word *about;* and the main point in the interpretation is how much variation from the exact figures given can be allowed. We cannot get perfection; it is useless to try to get that in this world, and as its substitute, we must get as close as possible, and as practicable. It is a question of practicability *versus* perfection, and the man who has the good judgment to get the best practicable is the successful man. As was said by one of Massachusetts' most prominent men at the inaugural of a president of one of Massachusetts' most famous institutions: "He has learned to do justice to opponents, has

become convinced that it is better to get the *best possible* than to prate idly about an *impossible perfection;* find fault perpetually and get nothing."

These words are a whole sermon to me, and one we would always preach (did we preach) to young engineers. You engineers know so much more than we contractors that you often assume we know some little you know. You put common words into a specification, which words have a common meaning to us, and then when we get to work, you bring out your interpretation of those common words.

For instance, " coarse, sharp sand shall be used." Does this mean that 27 per cent. of this sand shall pass a 200 sieve, or that 86 per cent. shall pass a 27 sieve? We never did nor do we ever hope to know. If size of sand is to be tested by a sieve test, specification should so state.

" *Cement* shall be of a well-established brand, shall be subject to inspection and rigorous tests of such character as engineer shall determine." Does this mean, in the entire absence of any detailed chemical composition, that we shall furnish cement having abnormal proportions of sulphuric acid, magnesium and of lime, either high or low?

" A pile shall be at least 6 in. at tip, and *not less than* 30 ft. long." Does this mean that the minimum of 6 in. for tip and 30 ft. for length shall be allowed to be used, and as much larger tips or longer length as the engineer may require, or does it mean no pile can be required driven with a larger tip than 6 in. and a longer length than 30 ft?

" The stone used in the work shall be from one quarry, shall show no streaks or sap or other imperfections and shall be uniform in color." Does this mean that each single stone shall show no sap or streaks and shall be uniform in color, or does it mean that all the stone in the work shall be of the same color, with no streaks or sap?

Timber attached to masonry. " The contractor will be required to embed in or attach to the masonry sills and bearing timbers and such other timber as may be required."

Definition of timber, according to dictionary: " Wood fit for building; a piece of wood squared or sawed."

Can you conceive of a frame, with bolts and bearings, fitted for gates, for door frames, window frames, and I don't know but mosquito frames will come later, being considered as *timber*, to be set at a given price per thousand?

Should not specifications be explicit on these points, that a contractor can know on just what he is bidding?

The engineer should know what he wants when he writes his specification, and should state it, and not come around after the contract is signed, all material contracted for, and then bring out some special tests wanted, some wire factory work, or some special interpretations which the contractor never heard of.

Very much trouble comes from masonry inspection, the quality of the cutting, the size of the joints, plug holes, etc.

Regarding the matter of masonry joints, I want to say a word. Early in our engineering days, we were talking with a stone man about good joints, and he told this incident:

He cut some large stone for a government job for engine beds, and the specifications called for pean hammered beds and joints. He made them, work was accepted and built. In a very short time, under the vibrations of the engines, the joints parted. The stones were taken out, " plugged " good and hard, and put back, and stood the vibration without trouble.

At Portland, Me., is another government job, a small arch, where the joint next the skew back is about a $\frac{1}{4}$ in. The whole length of the arch stone has split off, owing to thin joint.

To-day there is another arch, the longest railroad span in the country, standing without trouble under a terrific load, with mortar joints which will average 2 in. thick.

We give these facts to show the trouble which has come to fine small joints, and also to show how much a large joint, built solid, can stand. But stone is hard and tough, and the men who cut it are equally hard and tough, so that much trouble comes to work where the stones are all "*specials*," and some one is plugged too hard, cut slack or is off-color, and the whole job has to shut down to wait for a new stone from a quarry a hundred miles away.

We can't ask you to discharge your inspectors and take everything that comes, but we can and do ask for reasonable inspection, for a consideration of the means through which material is obtained and manufactured; that when you want a monument you ought to have it as good and true as man can make it; but when work goes out of sight, under ground or under the sea, a pea-green stone is as good as cadet gray, and a $\frac{7}{8}$-in. joint as good as a $\frac{3}{8}$-in.

Generally speaking, we do not cut or furnish the stone, and the loss of a condemned stone doesn't fall on us, but the spirit of getting a " pound of flesh " is what makes the trouble, and extends from the contractor, through the superintendent, foreman, masons and even to the water boy.

If a contractor, bidding on public works to-day, ever tries to figure on all the chances which may come up, he never will get any contracts. He has to run the risk, to trust that some things will come his way, enough to balance the things that go against him. He doesn't want to be always kicking, making claims for extras, for small things, in the hope that the engineer will give him the benefit in doubtful cases, and such advantages as the work may offer, enough to offset his little extras. But when he doesn't get any of these benefits, especially if he feels that the engineer is willfully withholding them, is compelling him to do the work to the exact letter of the specifications, where such work is of no value to any one, when he is, in the common term of the profession, "getting roasted," then comes trouble, claims for extras, kicks and general eruptions.

Do you know what the lack of a square deal means? That the other fellow denied this now great American right has it in his heart to "get even" with the man who denies it to him, and it takes a good Christian and a square man to curb that impulse.

To give and to take, to do justice on the one hand, and good, honest work on the other, and then settle the differences, man to man. Then lawyers will go out of our lives, courts be left for the Boston Elevated cases, and then will come the day of good-fellowship and regard which should exist between the creators and makers of this modern world, the engineers and contractors.

The following quotations are taken from a personal letter of Mr. Seth Perkins, civil and contracting engineer, of Boston:

"The traditional and proper function of an engineer as related to contracts is to act as an arbitrator between two parties to a contract, and as all contracts are presumed to be conceived in fairness every impulse of an engineer should be to measure the fair rights of each party in having the work properly carried out.

"Theoretically, works are designed and specifications and plans are drawn to give true and graphic exhibits for the purpose of obtaining competitive bids.

"Practically, engineering is not an exact science, nor can it be on account of the many uncertainties bound to exist, which only develop into certainties as the work progresses. The engineer animated by an idea of fairness could draw his specifications in such a way as to definitely specify known factors, and provide for the unforeseen conditions in a way which would insure justice to both parties. But this never will be done while engineers work from fixed clauses probably dictated by a mind trained in legal thought and without the elasticity which is the outgrowth of engineering experience. I feel in many ways that the engineering profession has been made subservient to the legal, and I think to

its detriment. There is no profession in which the training tends so much to analysis and by force to synthesis. Then why should we allow the legal profession to dictate arbitrary clauses in specifications which are in conflict with our judgment and bound to place us in a false light? The only use to which I have been able to put the legal profession is to unravel snarls of their own making, and then they had to call for expert knowledge where the knots were too tightly drawn. I suppose the burden of your argument will be objections to the arbitrary clauses in contracts and I think they should be attacked. For when controversy arises, as is often the case, where unforeseen conditions come up that have not been made the subject of particular specifications, the usual result is to fall back on general clauses which are generally arbitrary, and if the controversy assumes the proportion of litigation the interpretation of these clauses is left to a Court having no training which would entitle him to judge what was the original intent of the engineer responsible for the specifications or the spirit they intended to convey."

DISCUSSION.

MR. H. H. CARTER (*by letter*). — Two or three years ago I took considerable interest in the matter of Mr. Rollins's paper. I appeared before a legislative committee for two successive years endeavoring to have a law passed making it obligatory for the commonwealth, cities and towns to introduce into their contracts an arbitration clause instead of the present clause making the engineer sole judge of everything.

The matter has largely gone out of my mind at the present time. I will, however, look through a Transit Commission contract and mention a few points.

First. Contractors object to the present clause making the engineer referee to decide all questions relative to the *fulfillment* of the contract, and that his estimates and decisions shall be final and conclusive. It seems to me while the engineer is properly made the judge as to the fitness of materials, he certainly should not be referee to decide all questions relative to the *fulfillment* of the contract, and that questions of that sort should be decided by three parties, one to be appointed by the commission, one by the contractor, and these two to select a third. This provision you will find in force in the contracts drawn up by the Master Builders' Association.

Second. Contractors object to the clause stating that "if delay occurs on the part of the commission in furnishing the material, or if the contractor is delayed by other cause which is not his fault, the contractor shall have no damages on that account," etc. This is manifestly unfair.

Third. Some contracts contain a provision that in figuring the cost of extra work the contractor shall not be allowed to have superintendence, liability insurance, etc., figured in. As these are matters which all enter into the expense of the work, they should be taken into account in figuring the expense of extra work. Liability insurance in some instances amounts to 9 per cent. of the pay roll, and there is no reason to leave it out as an item of expense in contract work.

Fourth. I think the time has now come when engineers should entirely revise the present form of contract and specifications and draw them up in a spirit of fairness to both contracting parties. The present form of contract arises from one engineer after another, assisted from time to time by a petty lawyer, endeavoring to alter the previous form of contract and introduce some ironclad clause, still further tying up the contractor body and soul and throwing on him the risk and expense of work which justly the other party to the contract should bear.

Fifth. All clauses requiring the contractor to do certain work at his own expense, "*unless otherwise directed*," should be done away with. Such clauses throw doubt on the good faith of the engineer and leave the contractor in doubt as to how he should make his figures, and also give him the idea that some other favored contractor knows in advance how the engineer will direct.

Sixth. All clauses should be done away with giving the right to the engineer to deprive the contractor of compensation for necessary work done under the contract. For instance, a recent sewer contract contains provision for 5-inch tongued and grooved sheeting driven below grade. The engineer has the right to order it taken out on the completion of the work if he so elects in which case the contractor receives no compensation for furnishing and driving it. If it is left in, however, he receives $70 per thousand feet board measure. This item alone on the particular contract referred to left the contractor in doubt as to whether or not he would receive any compensation for $40 000 worth of prescribed work. This is the kind of clause, when it is shown up in court or brought before the public, that throws suspicion on contractor and engineer alike. The idea that $40 000 worth of work *done* by the contractor may be paid for or not as the engineer decides, by a stroke of the pen, is one that sets ordinary people to thinking and does much to keep alive the continued talk of graft in connection with contracts.

Seventh. All clauses requiring the contractor to do work at

his own expense when such work is not contemplated by the plans and specifications should be altered, and if such unexpected work is necessary, the clause should read that such work is to be done at the expense of the other party to the contract.

I must say that once in a while it is a satisfaction to see the engineer "hoisted with his own petard." The recent trials of an engineer for fraud in connection with a large filtration plant were based on a lot of fool clauses in the specifications which an alleged set of reformers thought should be interpreted to ruin the contractor. For instance, the borings for a filter gallery covering a large territory showed that the material was all clay and gravel. The engineer unthinkingly put in the clause relating to excavation that the contractor was to excavate to the prescribed line for the concrete foundation, and that if any soft material was encountered below this line it was to be excavated and refilled with concrete at the contractor's expense. The contractor gave a lump sum bid on this work, and as the borings showed hard ground, he naturally made no allowance for excavation and refilling with concrete below grade. After the work was completed, an area of over an acre was discovered which contained muck running as much as 15 ft. below grade. This meant about $200 000 worth of work to be done by the contractor at his own expense. He naturally objected to doing this work without compensation, and had a hearing before the proper authorities, who decided that in view of the fact that such a large amount of extra work was not contemplated by the original specifications, that he should not be obliged to fill the excavation with concrete. After this decision the Philadelphia Goo Goos, or some similar organization of broad-minded individuals, thought that there must be fraud, and the engineer was arrested for abetting it. The trial naturally resulted in the acquittal of the engineer. It is safe, however, to assume he will rewrite the clause about refilling below grade and put it in such terms that in future he won't run the risk of going to jail because he recommends that the contractor shall not be driven to bankruptcy by the enforcement of clauses which were written to cover entirely different conditions.

Mr. Rollins has put the whole matter of these contracts and specifications in a nutshell when he uses the term "a square deal."

Unfortunately, the training which some engineers go through, unless they are big broad-gage men, seems to shrink them up into the class that looks on the cent as the ordinary man looks on the dollar.

When engineers realize that pettiness and meanness and the desire to be unfair to other people, as exemplified by the way they write specifications and contracts, only reacts on themselves and gives broad-minded people an idea that they are a small class of people, to be paid and considered accordingly, — when they realize this, then perhaps we shall see a fair set of specifications.

Mr. Charles G. Craib. — If I were a lawyer and were conducting a case, and you were the jury, after hearing Mr. Rollins I should say I would be very well satisfied to rest my case. He has presented the objections to the average contract and specifications in engineering works in a very able manner, and I don't expect to be able to add anything to what he has said along that line.

There is a fictitious value created every time you add a hardship to the parties that are going to perform any service, and it seems to me that that feature ought to be considered in connection with a matter of this kind. I haven't had a very large experience with engineers, but such as I have had has made me feel that professionally they stand at the head of all others; that they contribute more to our general welfare and to the general advancement of all of our interests than any other profession. Most of the good clothes we wear and the comforts we enjoy are sometimes said to be the direct result of education. I think they are largely the result of the work of the engineer. So that it is without prejudice against the engineer that I make any remarks.

Before going into details on the subject of contracts, and to show how this clause that has been referred to in the specifications, giving so much power to the engineers, works to the detriment of the contractor in an unfair manner, I will speak of the contract that I had in a city not far from Boston. We had a trench, not very deep, but it seemed to me that you'd stand about as much chance to put a pump on a raft in Boston harbor and try to pump the water down as to pump that trench. After opening a large section of it, it was necessary to have a large number of pumps, and it was thought best to move those pumps on Sunday. The next Saturday night at 12 o'clock we began making the change, so that the work would be in a condition for digging the next Monday morning. But under this general clause in the specifications the engineer took it upon himself to come out Sunday morning in the midst of the operations and stop the work simply because it was being done on

Sunday. There is no law I know of, as this was so far removed from dwellings as not to be a nuisance to any person, under which he could do that except by placing a very broad construction, from his point of view, on that clause in the specifications giving him the power to regulate the contractor's work. There was a case where it worked very much to the disadvantage of the contractor. Another case occurs to me, in a town which has since become a city, in which the pumping was stopped in the middle of the day on Sunday by the engineer because there was an objection made by people who attended the church close by. I shouldn't have thought very much of that if I hadn't known that a number of the people who made the complaint were interested with Jernigan in trying to extract gold from sea water and to sell stock for that undertaking. I thought that their religious scruples were rather far-fetched in my case, but of course they had to act through the engineer, which they did. In another case I contracted to lay a 20-in. pipe in a trench, and the engineer specified how the joints should be made. A string of jute was to be inserted in each joint. The pipe was furnished under another contract by the town, and I think that out of 550 ft. we found four pieces that would go together without chipping. Still the engineer insisted that we should chip off enough to get the jute in, because the contract specifications required that we should do that. Those little things form the reason why contractors and engineers are at odds at times. It is not the general specifications. I have read through carefully during the past few days several sets of specifications, and I cannot find a word anywhere that I'd be willing to cut out, looking at it from the point of view of the citizen. The speaker was superintendent of a large sewer contract, where the contractor would not do certain things that were necessary for the success of the enterprise because of the expense; when failure seemed inevitable, the engineer took charge of the work, with the result that the work was put on a good financial basis, turned over to the contractor, was continued by him to completion, very much to the satisfaction of all parties interested. The one trouble is that we don't have engineers to deal with such as are now at the head of the departments of our public works in all cases. If we had, there would be no trouble. But to explain my meaning, I might tell you what happened in the case of a young engineer I heard of. He got his friend to bid on a contract, and he made all kinds of absurd conditions and inserted them into the specifications, and said to his friend, "Why, that is all right. I just want to

make a good contract, so that they will know that I have attended to my duty. There will be no trouble about the work, because I don't intend to enforce any of these conditions." His friend took the contract and the young engineer died. Another man came along and enforced the conditions. So you see if we only knew that the man who draws the contract is the man who is going to construe it, and that he is a man like our presiding officer to-night, there would be no trouble. But it isn't always so. The general objection to general specifications is not that it is not wise to have a good strong set of specifications, so that the engineer can have control of the work, but it is that some engineers take advantage of that and neglect to give the contractor's side of the question proper consideration. At this time, when so many engineers have taken up the contracting business, some arrangement could be made by which a general form of specifications might be recommended that would be more in a spirit of fairness to the contractor and in justice to both parties to a contract.

Mr. Charles R. Gow. — I believe Mr. Rollins is to be commended for the introduction of this somewhat novel discussion, in which nearly all of us are interested on one side or the other.

Possibly his remarks and arguments may appeal to many of you as engineers in a way that will be beneficial to others of us in the future as contractors.

As pointed out by him, there has been a combination of engineering and legal skill working together for many years past in an endeavor to evolve certain standard types of specifications and contracts designed with a view of securely fixing the responsibility for all uncertainties and unforeseen future contingencies upon the party who has no voice in the framing of the contract, namely, the contractor. That this united effort to reach perfection in the matter has not been entirely successful is evidenced by the number of cases which still require the final adjudication of the courts. That it has been for the most part successful, however, can be testified to by many of us, who have paid dearly, from time to time, for the privilege of learning this fact.

It is probably no exaggeration to say that this disposition to, in a sense, take advantage of the contractor by the shrewd wording of the text and skillful evasion of responsibility has been the cause of more dishonesty on the part of contractors than any other single reason.

How often we have heard our engineer friends condemn, with righteous indignation, the habit of the contractor who studies the contract and specification for some loophole or omission through which he may legitimately claim additional compensation or relief from onerous requirements. How often also have we seen the same engineer, when he discovers that he has failed to foresee and provide for some contingency which has arisen, take refuge behind some blanket clause, which never contemplated this particular contingency when it was written. Are not the two traits identical? The contractor seeks to safeguard his pocketbook and the engineer his reputation as a far-seeing and shrewd official.

I agree with Mr. Rollins that the greatest absurdity that exists in present-day contracts, from the standpoint of fair play, is the clause making the engineer sole arbitrator in cases of dispute.

It is inconceivable to me that any man who must of necessity be a party to the dispute, and having made up his mind in advance, could or should desire to exercise the judicial function of a referee in deciding whether he or the other party is right. It is a fact that this clause is accepted by 99 per cent. of the practicing engineers as a mere subterfuge to escape the consequences of arbitration and to bind the contractor to abide by the engineer's decision, regardless of the merits of the controversy.

I have never known but one engineer in my experience who admitted that this clause could, in any way, operate in the contractor's favor. Fortunately for the contractor, the courts have placed some limitations upon the extent to which this clause may be applied.

Not only are we obliged to accept the engineer as referee, but in addition must agree that our methods, men and materials will be acceptable to him, and that he shall finally decide whether or not we are entitled to any compensation, and if so, what amount. Can you not imagine that under these conditions the personality of the engineer will enter largely into our estimates of costs? Some engineers we do not care to work for under any circumstances. Some require that we add a large percentage to our figures to provide for their close and arbitrary dealings and interpretations, while still others are known to us as fair and liberal-minded men with whom we feel justified in taking chances and have confidence in obtaining a square deal. Some engineers accept a contract in the same spirit that they

would the gospel, as something inviolate, any deviation from the letter of which would condemn them to perdition for heresy, while others are willing to look upon it as a purely business agreement, to be carried out for the best mutual advantage of the two parties. Is it difficult to guess which engineer will obtain the lowest prices on his work?

As contractors, we naturally expect to assume certain risks. We admit that we must be expected to gamble on the labor conditions and prices; upon the fluctuation in cost of materials, upon the effect of weather changes, upon errors of judgment in making our estimates, upon freight delays, upon the possibility of serious accidents to persons or property and other features of like nature; but worst of all is the gamble we take on the uncertainties imposed upon us by the contracts and specifications, when we assume responsibility for all delays caused us by the owner, for all errors or inaccuracies in studies or plans, for all oversights on the part of the engineer, and not infrequently for the correctness of the engineer's lines and grades.

Added to all this is the uncertainty of the disposition of the particular engineer and inspector assigned to supervise our work and upon whom we must depend for the interpretations of the very elastic wording of the specification.

As to the specifying by the engineer of the detailed methods of operations, my opinion is entirely in accord with that of Mr. Rollins. I fully believe any unbiased individual will admit that the average contractor is a far better judge of the proper methods to obtain desired results than is the average engineer, yet a majority of the engineers seem impressed with the idea that their technical knowledge entitles them to the privilege of directing the contractor in the management of the details of his business.

As an example, I was once consulted by a prominent engineer as to the proper procedure in a matter of which this engineer had no previous experience. He requested my opinion on account of certain successes I had made in the class of work under discussion. Subsequently he embodied in his specification the general method outlined by me, but in addition also his own conception of the detailed manner of carrying on the work, a conception which, by the way, was erroneous. It so happened that I was the successful bidder, and much to my surprise and disgust was obliged to follow out his ideas in spite of my protest, with extremely unsatisfactory results both to the engineer and myself.

Another habit which is growing among contract writers is that of specifying prices for certain items. While I can see no good reason for usurping this one of the few contractors' privileges, there would be no serious objection to this habit if the engineer would commit himself definitely as to the probable quantity involved. I have never known an engineer to specify an excessive price for any of these items, and usually the contractor prays that there may be no work of this classification if he must accept the price set.

On a certain contract executed by our firm, a price of $13 per thousand was stipulated for sheeting left in place. No estimate was given of the probable quantity to be used, but it seemed likely that the amount would be inconsiderable. On the contrary, there were 150 000 board ft. so left in place, costing us for the lumber alone $22 per thousand, and representing a loss to us of $1 350 outside the labor cost. A protest to the engineer against this arbitrary allowance on so large an amount was met by the argument that we should have taken it into account in making up our bid; but how could it be considered in the bid when the amount to be used was absolutely unknown? We were then reminded by him that we should not have bid on the work if we did not like the specification. This argument is in line with that of the railroad official who tells you that you do not have to ride on the cars if you do not like the service. You can get an automobile or walk.

There is a very general tendency among engineers, and I can refer back to the time when as an engineer I did the same thing, to make certain requirements simply because they are called for by the specification, and regardless of whether or not they are necessary in the sense that the specification intended. Undoubtedly every clause contained in a specification had originally some reason, either good or bad, for its existence. Too often, however, many of these clauses are enforced against the contractor without any reason.

I was at one time prevented from using second-hand lumber in foundation platform, not that the quality of the lumber was in question, not that it would not fulfill the function as well as new lumber, but merely, as the engineer explained, because the price stipulated for this item contemplated the use of new lumber.

On another occasion a contract for a certain state commission called for the use of several thousand barrels of cement

of a brand acceptable to the engineer. A canvass of prices obtained from the cement dealers showed one brand to be quoted 30 cents less per barrel than the others. Upon submitting the matter to the engineer I was informed that this brand would not be accepted, and the higher price was therefore paid. A few weeks later I learned that this same engineer had contracted for a large order of the cheaper cement for use on day work being done by the same commission after bids for the work had been rejected as being too high. The same specification for cement had previously been used by the bidders on this work as applied to my work. On the same contract I was required by the engineer to suspend work until heating arrangements satisfactory to him were installed, while a personal visit by me nearly a month later to the day work referred to showed absolutely no attempt at heating or heating apparatus.

All these things illustrate the fact so long realized by contractors that the strict wording of contracts, together with the extraordinary powers delegated by us to the engineer, often serves as an inducement to him to exact everything from us that he can possibly obtain, regardless of necessity, so long as no additional expense is entailed to his employer. As soon as the expense becomes a matter in which he is personally interested, his views often experience a strange and violent change.

Still another matter which oftentimes causes unnecessary annoyance and hardship to the contractor is the tendency of engineers to retain all of the contractor's money that their consciences will allow. The general rule appears to be, "In cases of doubt, hold back enough."

First we are required to furnish a bond of from 20 to 50 per cent. of the amount of the contract. Next a reserve is retained of from 15 to 25 per cent. of our monthly estimate. Before the allowed estimate becomes payable to the contractor, from one to three weeks' additional work has been completed and forms an additional security to the owner.

It would appear to an ordinary individual that the above items would amply secure the owner against any breach of contract on our part. The average engineer, however, takes a different view of the matter, his idea of an approximate estimate being one that is well on the side of safety, for why should the contractor complain when he knows that he is to receive the remainder upon the completion of his contract some months hence? Meanwhile the contractor must pay 100 per cent. of

his pay roll every Saturday night, and if his material bills remain unpaid after thirty days, the various credit agencies are investigating his financial condition.

If engineers were obliged to pay 6 per cent. interest on all reserves, it is safe to assume that they would soon experience a change of heart.

Practically all of the evils referred to are attributable to the blanket clauses contained in our contracts. There is undoubtedly a necessity for the insertion of certain clauses of a general nature which cover certain specific classes of work. These are understood in advance by the contractor, are accepted in their general sense and provided for in his estimates. It would seem, however, that the English language is sufficient to fully cover and clearly explain every individual thing that the contract is intended to cover, the general method of procedure expected and the prices for payment of same, without resorting to vague and indefinite blanket clauses which mean nothing to us when figuring the job, but which may mean thousands of dollars before the work is finished. The presence of such clauses in a contract may be accepted as a confession on the part of the engineer that he does not know in advance what he may or may not want the contract to cover.

In conclusion I would suggest that when engineers, as a body, concede that the business of contracting is a legitimate and honorable profession, requiring a marked degree of ability, knowledge and experience; when they are ready to coöperate with and not antagonize the contractor who is trying to fulfill the requirements under trying conditions; when they recognize the fact that they have no right to expect something for nothing, and when they are willing to deal with the contractor in the same spirit of fairness and charity that they would with their grocer or other dealer at home, then, and not until then, can we expect perfect harmony and mutual understanding.

So long as they insist (as Mr. Rollins has put it) upon " their pound of flesh," just so long may they expect we will give them an interesting time in getting it.

Mr. E. S. Dorr. — If the contractors have nothing more to say, I think something might be said on the other side. Mr. Rollins has given us an excellent disquisition on what a contract should be, how it should be drawn for a fair-minded contractor. He has not told us what sort of contract we should draw when we have to deal with an unfair-minded contractor. It should be remembered that when the contract is being drawn the engi-

neer does not know what kind of contractor is going to get the job. He has got to assume that he will not be a man who will meet him in this fair spirit, and therefore he must trust to the contract, and he draws one that will give him the advantage. That is to say, if a controversy is going to ensue, and the very practical question comes up as to who is going to have the whip hand in the contest, of course the engineer will try to secure it for himself. And I think in that consideration is to be found the answer to the question why these clauses are kept in. Of course, if the engineer be a fair-minded man, he is not obliged to do an injustice on account of having the ability to do it. But he is enabled by the presence of these clauses to do justice, because, having the whip hand, his hand cannot be forced by the contractor. I think that is the only justification for the presence of these clauses which our friends have been inveighing against. If all contractors were fair-minded and honorable men, I would agree with Mr. Rollins and the other speakers that these clauses would have been very much better left out.

Mr. L. S. Cowles. — I think some of the unpleasantness that arises at times after contracts have been signed might have been avoided if, in looking over the bids, due consideration were given the contractor. In looking over bids, a corporation or an individual naturally will select the lowest responsible bidder. But perhaps those bids have been sent in under a misapprehension, and this responsible bidder who is the lowest has made a mistake in making up his bid. In that case the engineer, before the contract is signed, should call the attention of the corporation he serves to the fact that he thinks there has been a mistake, and as a result the contractor is notified and is allowed to change his bid. Under those circumstances perhaps he would no longer remain the lowest bidder or would be given a chance to withdraw. In a case that I recall, a Boston contractor had neglected to include in his bid some 1 200 oak piles and the driving of the same, which was quite an item. The result was that his bid was the lowest by far, and on calling his attention to the fact that he must have made a mistake, he admitted that he had made up his bid on a Sunday evening when some folks came in to call and he hadn't got as far as those piles and so left them out. But he came out man fashion and said he would see the thing through at his own loss. He was released, however, and the next lowest bidder secured the contract. That, of course, was before the contract was signed. So in treating the contractor, as Mr.

Rollins has said, man-fashion, he was enabled to withdraw without pecuniary loss.

Mr. Edward S. Larned. — I do not speak at the present time from the standpoint of the engineer who is directing the work, nor from the standpoint of the contractor who is performing it. But I have been, in times past, in the position of the engineer directing the work, and I think some of the statements of the contracting engineers who have spoken this evening are worthy of very careful consideration. It is not so much the specific terms of the specification as it is who is going to interpret the same, and in my experience it has come to be largely a matter of personal equation, and if this was more generally impressed upon the minds of engineers and their clients they would see the full significance of it. I haven't a doubt that on some work the cost is enhanced from 10 to 15 per cent. by reason of the fact that certain engineers are going to direct it. Contractors know by previous experience that they must allow at least that much margin to cover the exacting requirements of the engineer directing the work. It is not that such engineers get, perhaps, a better quality of work, but it is because they are, in the minds of contractors, unreasonable in their requirements.

Another feature of engineering control which is of very great importance to the contractor is that of the function of the directing engineer or the inspector. Now on some work it has been found that inspectors who were intrusted with the passing upon the quality of materials and workmanship do not stop with that, but in their zeal and interest they go further. They attempt to direct the work. In other words, if the contractor is a man who is disposed to resist the dictation of that sort of an inspector, he may, under some conditions, claim that it is interference, and under the strict interpretation of the meaning of the act, the inspector is interfering. And in just so far as he does that he is doing the contractor a very great injustice. The contractor, on the other hand, realizes that it is policy for him to be reasonable, amiable and willing, and he oftentimes does things that he knows are causing him a very serious loss in the performance of the work. But he does it as a matter of policy. In my experience I have seen a very great change in just that feature of engineering work. I think there has been a distinct progress. Things are very much better now than in times past. Chief engineers have come to appreciate that they must look after their engineering assistants a little bit more

closely, and that is a feature I would like to call attention to. Oftentimes contractors are not so much afraid of the interpretation of the engineer who draws the specification, or the man who is really in charge of the work, as they are of the assistant who is put in control of the work. Oftentimes the chief engineer is far removed from the source of the trouble. He may be fifty miles or even much further away, and it takes a long time to bring in a question of arbitration. A contractor is reluctant to resort to that. He knows it is policy for him to conform in every way to the desires of the assistant in charge of the work, and naturally refrains from reporting to the chief engineer that he thinks things are being done that to him are an injustice. This is a very important feature. And in connection with that I have often seen the importance of having a more intimate association between the chief and his engineering assistants. It would be a very helpful thing if chief engineers could bring their assistants together at stated intervals and have an exchange of ideas, a sort of question-box proposition, and let the young engineers or inspectors, who are the men directly in charge of the work, bring up questions of doubt or in dispute so the chief may discuss and explain the same, and in this way educate and broaden the men intrusted with the carrying out of his ideas. There is no question that every young engineer needs broadening, and if he has found his experience on one work alone, it is to be presumed that it will be years before he will be able to take a specification and interpret it rationally. You will find a difference between the interpretations of engineers in different parts of the country. New York is one thing, Boston another, and the Middle West and the Far West another. Experienced contractors take these things into account when bidding on work. It is not that the quality of the work is better in one case than it is in the other. . . . Now as to the engineer's not knowing in advance who is to take the contract. I don't like to designate a claim of that sort as being somewhat lame, but I think it could be very justly termed so. In the advertisement, and in the contract itself, the engineer distinctly reserves to himself the right to award the contract to the contractor who will best serve the interests of the other party. If a contractor is notoriously dishonest or untrustworthy, even though he be able to furnish bonds, there is no reason why the engineer should award him that contract. He would simply be inviting trouble. He should exclude that man's bid. Why does any reputable contractor make a reputation for himself? That is his capital,

and if by so doing he can get contracts at a better price, he is entitled to them. There is no profit to an engineer or a corporation or an individual in having disreputable contractors do work. Trouble is bound to result, and nothing good can come out of it. The fact that contractors take chances in specifications is a well-known fact. I don't believe one contractor out of ten reads the specifications in advance of his bidding carefully. He inquires who is the engineer. I don't think that is overdrawn a bit. In the last few years I have served in the capacity of adviser to contractors, engineers and architects, and have figured some work with them, and it has been particularly interesting to me to find the attitude of contractors toward engineers. When I inquired of them if they knew specifically the features of the work they said, " No, we know the specifications call for concrete of certain proportions, rock excavation, earth excavation, piling, embankment, grading, etc.," but the particular requirements that mean cost are not so much referred to as is the question of who is to be the engineer. I think the significance of that is not to be overlooked, and if the engineer makes a reputation of being fair and practical in all matters of arbitration he will find in his following a class of contractors who will bid fair prices on his work and give him good quality and progress at all times.

In the matter of specifications covering the materials, I think there has been an advance in that in the last few years, and I refer more specifically to cement specifications. Four or five years ago there were something like two hundred cement specifications in force in this country. You can understand what the manufacturer was up against. It absolutely forbade a uniform product. A mill was in the habit of catering to certain interests, and in doing so they, of course, observed those specifications. But if they went outside they were immediately in difficulty. Now that, happily, is over. We have, in 1904, adopted by the American Society for Testing Materials and American Society of Civil Engineers, what is known as standard specifications for cement. That is practically the basis for all the leading specifications to-day, and that difficulty is overcome. If, as in the instance referred to by Mr. Gow, the engineer denies the contractor the privilege of buying a cement over 30 cents cheaper than any other brand, and reserves to himself the right to select that for his own use in similar work, the contractor has redress in his own hands: he can submit that cement to a test and if it meets the requirements, — and there must be some re-

quirement beside the personal will of the engineer,— if it meets the requirement, the contractor can use it in the work. The question of contractors protecting themselves by taking exception to certain features of the contract or plans is a very important one. It is about the only means a contractor has to protect himself in a case of doubt, and I don't believe the time will ever come when we shall have a different condition in that respect.

Specifications at best are general in describing work. Plans in many instances can only be general, and there may be many details to add. And if, upon the development of the work, conditions arise that result in very material change, and the engineer is disposed to confine himself to the most economical design originally suggested on the basis of assumed conditions, irrespective of the contractor's rights and interests, then the contractor must, for his own protection, formally and by letter, state his position. I know of successful contractors to-day who make a practice of doing that even where there is no occasion for doing so. It is a matter of policy with them. The moment they feel in doubt in the slightest degree about conditions or results, they write a letter to the engineer that puts him and them on record, and if it comes to a judicial adjudication of the case, they have established their case in advance and fortified themselves very materially. From the standpoint of the contractor it is a pretty good policy to follow. The question of the intent of specifications and plans is a very broad one. One might take exception to many variations we find in interpretations of that nature. And it all comes back to a question of personality. The reasonable engineer is as explicit as can be under the conditions, and in the enforcement of contracts he is still reasonable and still practical. And if he is all that, he is all the contractor can expect. One great trouble with many engineers is the fact that they are not practical. Their ideas are very good; their judgment as to results can't be challenged; but their judgment as to the method of getting those results is sometimes very open to question. If an engineer lends himself to controlling the contractor in his methods, he makes a very great mistake, in my judgment. He would better let the contractor take his own way, when possible, and then pass upon the results.

The low bidder in competitive work frequently names ruinous prices if the contract be rigidly enforced and any unexpected difficulty arises; this means, as a rule, only trouble for

everybody concerned and demands from the engineer the utmost vigilance, tempered with justice and equity, and his capacity for inspiring confidence, rendering every legitimate aid in his power and maintaining pleasant relations with the contractor, has much to do with the final result.

When contractors willfully speculate in their bid prices and then depend on their ability to deceive the engineer or his non-enforcement of the specification, they deserve all the trouble, expense and loss they sometimes suffer. Mutual confidence, well justified, spells success to both engineer and contractor as a rule; if the engineer be narrow, mean and impolitic, he will find some contractors able and ready to go him one better and it is well for this engineer to remember that it is a case of one man or at best a few men against an organization.

Mr. Edward P. Adams. — The engineers have heard from the contractors, and while the contractors are here I should like to have them hear something from the engineers. And the reason I speak just now is to emphasize one point that, it seems to me, we should bring out: the fact that the engineer is or should be in a little different position from what the contractors have assumed that he is. It may be true that in public work the engineer has occupied the position that has been assumed this evening. But in private work, or at least on what I have had to do with, and what I have seen other engineers of long experience have to do with, the engineer does not stand in place of the owner against the contractor, but between the owner and the contractor. He has designed the work to obtain the best result possible. He has made the specifications in such a way that the contractor is in no doubt as to what is intended. He has so arranged his specifications that if there are any points which, from the nature of things, are doubtful, unseen, buried, those are to be paid for on a unit basis for quantities which the construction of that work will determine. So that when the engineer presents his specifications there should be just as little as possible of a doubtful element. And my idea is that this method of procedure is as useful to the one as it is to the other, — as useful to the owner as it is to the contractor. I recall now one case where the plans and specifications had been made for a piece of work, and the owner wanted a certain contractor to bid upon it, because he had done other work for him. Of course, naturally, I wanted other contractors to bid, and I called in some that had done work under my specifications. The result was that this contractor that had been named by the

owner bid in the neighborhood of $10 000, while one of the other contractors bid something under $5 000. And the reason was simply this, that this contractor who bid the lowest had been used to working under engineers, and he knew that engineers' work, properly done, would so arrange the plans and the stakes and markings that the work could be done in the most economical manner. It seems to me, therefore, that in private work, at least, the engineer can and should in every case work as well for the advantage of the contractor as he does for the advantage of the owner.

Mr. G. T. Sampson. — It appears to me, gentlemen, that the remarks of the contractors in this case have been offered as criticisms of the existing state of affairs, without suggesting any remedy. Certainly the blanket conditions of the specifications are drawn very arbitrarily, but it is necessary that the engineer in charge of the work should be upheld in his position and he should be recognized as the ruling authority in order that the work may be properly executed. His duty is in the nature of that of a military officer. He stands in the attitude of a military officer, and further than that, he stands as an agent or steward of the owner — the man who provides the money to pay for the work to be done. The whole subject rests upon the fundamental idea of money and profit, as the contract and specifications are prepared to define just what work is to be performed and material furnished for a given amount of money. A contractor goes to the bank, writes his note perhaps in the ordinary course of business, and he knows very well that he has got to pay the interest on that note. He knows that the banker is going to hold him right up to the full terms and conditions of that note, and that money put out at interest throughout the entire world demands just such returns and just such complete fulfillment. He takes such things as a matter of course and not to be changed. The contract for material and workmanship when signed is something of the same nature. Why should its conditions be considered less binding than the obligation of the banker's note? When the contract and specifications are executed the engineer is just as much bound by these conditions as the contractor himself, in that he stands as the agent and steward of the owner to see that the work is properly executed and the conditions fulfilled. These blanket conditions and general terms of the contract stand, we may say, somewhat in the light of the blue laws on the statute books — conditions and precedents brought down from years away back. It may be

that they are proper; it may be that they are unnecessary. Their need cannot be foretold before the prosecution of the work except on general principles. They are there as police regulations—in case of need to uphold the authority of the engineer. They have all been brought into this form which is in use to-day by exigencies in the past in which they have been found to be necessary. They are proved. They are the accumulation of the wisdom of many different men. It is a legal protection, and the law is determined in its judgments largely by precedent. I think engineers as a rule are held by the community at large and by all those who are acquainted with them to be men who are fair and just and honest, as much so, perhaps, as any other branch or set of professional men. Their training, their study, the solution of the problems which come to them, teach them to be honest. They know they won't get good results unless they adhere to the calculations on which their work is based. The engineer who designs a piece of work, if experienced and competent, knows best what is intended to be done; he knows the features of greatest importance; he knows those which are of lesser importance. Then let not the contractor, after accepting work under a specification, assume to vary from its conditions except by consent of the engineer and his employer. Man, however, is not infallible by any means, whether he is an engineer or a contractor. Some errors are sure to show up, and a properly worded contract should have a provision as a fair remedy for the same. It is a rule in business which can safely be adopted, I think, that the man who holds the purse strings is bound to get the worth of his money when he spends it, if he can. The contractor who quarrels with the engineer who is fair and honest and reasonable is putting himself in a wrong position. The minute he refuses to perform work which is specified he takes the ammunition or arguments away from the engineer who, however much he may have the disposition to favor him by arguing on his side with a superior officer or owner, cannot then consistently do so. When the contractor stands in the position of refusing to do things that are specified, the engineer cannot and will not be disposed to favor him or to ask for consideration. But if he does his work completely and thoroughly, and does it in a willing spirit, with the idea of doing the work right for the good of the work as it ought to be, the engineer is in a position where he can go to the man who holds the purse strings — the president of the corporation or any other official to whom he is subordinate — and with clean hands can

argue and persuade and coax, perhaps, for the fairest kind of fair treatment for the contractor in case a loss may result from a cause which was not foreseen. The general form of most contracts is, I think, a matter of precedent. The engineer in charge of a piece of work makes his reputation or loses it according as he is able to execute it successfully or otherwise within the limits of preliminary estimates and conditions. The corporation, public official or trustee, perhaps, that furnishes the money for a large undertaking is held by the banker, when borrowed money is concerned, to a strict accounting for every cent. The treasurer who keeps a record of the expense is accustomed to meet the banker and balance his books to the closest cent. He asks why is not the engineer to be equally accountable. Why shall he not fulfill conditions and obtain results down to the practical limit of precision which his profession teaches and claims, without asking for special exemption or privilege? That, in the abstract, is the power behind the throne, and a contract is prepared to protect the capital invested on a strictly business basis. It is generally recognized that there are uncertainties in contracting work, and the contractor knows it. His profession is a hazardous one. He takes the risks sometimes with large profits, and sometimes loss results. He can't expect to overcome all the difficulties. I think the veterans among the contractors recognize that it is wisdom and good policy and in every way for their interests to refrain from quarreling with their engineers. And when they are at peace, and when they do their work right up to requirements and do not allow the work to suffer at all in its quality, I think they may, as a rule, expect to get fair treatment, and I think they will find an advocate of their cause in case of need in every broad-minded, honorable and competent engineer. I conclude that any energetic contractor who so establishes his reputation for good work and square dealing can easily secure sufficient work to keep his plant employed so profitably that he can afford to turn away and refuse to bid on a proposition which may not be to his liking.

Mr. Frederic P. Stearns. — The paper of Mr. Rollins and its discussion at the meeting by other contractors were interesting, and will, no doubt, lead engineers to improve to some extent their forms of contract and specifications and to act in a less arbitrary manner in directing contract work. Probably all engineers of experience have known of many instances where engineers, generally the younger members of the profession, have given arbitrary decisions which have added much

to the cost of the contractor's work without materially improving the quality of the work under their charge, or they have modified plans in a manner to save some money for their client, regardless of the extra cost to the contractor of such modifications

As far as practicable there should be coöperation between the engineers who direct works and the contractors who execute them, to produce the required result at the smallest practicable cost. This is obviously for the benefit of both parties, because if an engineer unnecessarily increases the cost of a work, subsequent work let under his direction is likely to go at a higher price, and it certainly is a loss to the contractor if he cannot do the work at the lowest practicable cost.

In the writer's dealings with contractors in the past ten years there were very few who were not willing to do good work or who attempted to be dishonest in their dealings. When there has been trouble it has been, as a rule, with those who furnished supplies to the contractors. For instance, stone from one quarryman would come on the work cut substantially in accordance with the specifications, and in such cases an engineer should use many stones which do not come quite up to the requirements, provided the stone when in place would be reasonably satisfactory. On the other hand, another quarryman practically disregarded the specifications in cutting the stones and made them with much larger joints and not true to form. To have accepted such stones would have resulted in masonry of inferior quality to that specified and in paying a premium to the quarryman who did not do faithful work; moreover, only a part of the stone had been received, and if this had been accepted the remaining stones would probably have been even more carelessly cut.

There are several points which Mr. Rollins and others have made with regard to contracts with which the writer fully agrees. For instance, the contractor should not be held responsible for the stability of work designed by others provided the work is constructed as required by the specifications. There are, of course, exceptions to this rule, as it may be entirely proper to require an engine builder or a bridge company or other contractor with a large fund of technical knowledge to be responsible for the efficiency of a machine or other structure.

The writer had supposed that a court would not find a contractor for public works responsible for the stability of a structure made according to the engineer's designs without some specific agreement to that effect, until he was connected with a

case where a masonry dam failed in Alabama. In this case the dam failed, in his opinion, because its design was such that even if well built it would not resist the pressure of water at the height to which it rose in the river during a flood. The judge in this case ruled that the contractor would not have been responsible for the design of the dam had it not been that he had agreed in his contract " to complete the work and the whole thereof," and that it was not wholly completed. The dam was at the time completed in every part which affected its stability, so that the ruling of the judge was practically to the effect that the contractor guaranteed the design of the dam until its completion.

Such a decision, while it may be legal, is not equitable, as the average contractor cannot be expected to have the knowledge required for the designing of such dams, and engineers should endeavor to have eliminated from their contracts clauses which may result in such an inequitable decision.

There are many features of Mr. Rollins's paper with which the writer cannot agree after viewing them as nearly as he can in an unprejudiced way and from the standpoint of public policy. For instance, objection is made to clauses in contracts which in any way give the engineer control over the methods to be used to do the work.

It should be remembered in this discussion that we are dealing as a rule with contracts which are let by public advertisement, and in the majority of cases they are given to the lowest bidder who can furnish bonds and has a fair reputation for doing work, without regard to whether he has engineering ability or not.

The writer has often found it advisable in tunnel contracts to provide for adequate timbering, safety appliances in connection with shafts and cages and ventilation. This control has been found necessary in the interests of the health and safety of the workmen, because many contractors are willing to take risks which ought not to be taken.

As it is advisable not to have divided responsibility, the contractor is made responsible for the safety of the timbering, and the engineer's control is limited by the provision that he may require stronger timbering if, in his opinion, that proposed by the contractor has not sufficient strength.

It is also well that the engineer should have control of the time of removing centers from arches, as there is often a tendency on the part of a contractor who requires the centers for

use in another place to remove them too soon, with material detriment to the quality of the work, and, although the contractor is supposed to be responsible for the work, it is not feasible in practice to condemn completed work unless it is positively bad.

As a rule, the writer believes that the contractor should be left free to plan temporary works, but there should be exceptions to this rule when the works are so extensive that they require technical skill for their design and where the failure of the temporary works would lead to great delay and loss.

As instances of temporary works which I think it advisable to design and pay for, I would include large flumes for carrying the floods in a river past a dam during its construction, and important cofferdams. To leave these wholly to the judgment of the contractor and permit him to bid a lump sum on a work that is not designed seems entirely contrary to the interests of the intelligent and cautious contractor, as some more ignorant or venturesome contractor is liable to underbid him on such work.

The question then arises as to who should be responsible for such designs. If they were not liable to be weakened by the manner in which the contractor conducts his work, there is no question that the responsibility should rest with the party making the designs, but a cofferdam depending upon an earth bank for its stability may fail when the enclosure is pumped out if the water is lowered too rapidly, or, in the processes of excavation, the inner toe may be undermined and weakened and require bracing. It, therefore, seems clearly desirable, in order to avoid divided responsibility, to place the whole of the responsibility upon the contractor and to provide that he may strengthen the cofferdam as much as he wishes or may adopt other designs of equal or greater strength approved by the engineer.

In the case of a flume, which was built before the contract for a dam was made, to carry the water of a river past the site of the dam, the contractor was permitted to strengthen the flume if he thought it advisable, and was made responsible for maintaining the flume, because he would necessarily undermine it to some extent by his operations. On the other hand, he could not enlarge the flume, and the other party to the contract was made responsible for the damage, if any, due to inadequacy of size.

Practical experience shows that it is not wise, especially where work must be done within a given time, to permit a con-

tractor to take great risks, like that of the breaking of a coffer-dam, because it inevitably results in delay and almost as inevitably in a suit on the part of the contractor.

Especial objection is made in the paper to the clause in a contract "which makes the chief engineer the sole judge of everything," and arbitration by two persons, with a third one to be chosen in case they cannot agree, is suggested as an alternative. It must appeal to engineers and others that it is difficult, if not impossible, for an engineer who prepares plans, writes specifications and is interested in the construction of work at a low cost, to be entirely unbiased in his judgment. He is likely to lean either in the direction of his employer, or, recognizing his somewhat anomalous position, to lean toward the side of the contractor.

The suggestion of arbitration is always attractive, as one can picture two entirely disinterested intelligent persons of judicial temperament, who will listen to what is told them by the contractor and the engineer, and then proceed to investigate for themselves and reach an entirely fair conclusion; but experience shows that this is an ideal and not a practical condition in most cases.

The cases with which the writer is most familiar are those in which it has been attempted to ascertain the value of a water works property which has been taken by a municipality or a state, by a method which is very similar to the arbitration which is proposed as a substitute for the judgment of the engineer.

In these cases a commission is chosen, nominally by the court, but practically two members are chosen, one each by the two parties. Instead of selecting parties of a judicial temperament, who will be likely to reach about the same conclusion, one side selects a man noted for large awards and the other a man noted for small awards, and after considerable difficulty a third member is usually chosen who is more or less of an unknown quantity. Eminent counsel are engaged on both sides, with assistant counsel, and the country is scoured for experts, among whom will be found on one side those who are noted for the testimony they have given of great valuations of property and the others for lower valuations. The case then is likely to go on for a long time before it is finally concluded. There is one result which is certain to occur, namely, that a considerable percentage of the award is paid to lawyers and experts and for the expenses of conducting the case, and yet I believe the

results are not, as a rule, nearly as fair to both parties as the judgment of the engineer. In such arbitration there is nothing "of the old principle of man-to-man settlement."

A large share of the contracts are drawn by the commonwealth, the cities and the railway corporations, and in a law suit they are generally at a decided disadvantage as against the individual or the small corporation represented by one or more very active individuals; and those who draw the contracts will, and in the writer's judgment should, continue to draw them on the basis of avoiding litigation. He also believes this policy to be in the interests of the fair-minded contractor, who would not gain enough through arbitration or legal procedure to offset the extra time and expense involved.

Strong objection is made in the paper to the use of the words "except as otherwise directed." This provision, together with the usual provision that "the engineer may make alterations in the line, grade, plan, form, dimensions or materials of the work," may seem very arbitrary, but the writer has always assumed that it would not be feasible or even legal for the engineer to make radical changes under the authority given by these provisions and minor changes must be provided for.

It is suggested in the paper that "the contract must be explicit in all its terms"; also that "the engineer should know what he wants when he writes his specification." The writer has yet to know the engineer who, in connection with important work, is able to tell at the time he writes his specifications just what he wants in all details. He may know what he would like if the conditions prove to be as he expects, and yet is likely to learn during the progress of the work, especially where much of it is underground or under water, that the conditions are not what he expected and that there must be some modifications of the views which he held when he wrote the specifications. He should, in writing the specifications, state in them as explicitly as possible what is to be done, but for the benefit of his client and of the contractor there should be such provisions as those above mentioned permitting the engineer to modify the work in view of the further information obtained during its progress.

The contractor does not always recognize that the engineer is not a party to the contract and that he has no right to make any changes except as he is specifically given that right by both parties to the contract.

The writer believes that it would be unfortunate for the

contractor as well as for the other party to the contract if the engineer were not authorized to use his discretion as to changes in plan. Mr. Rollins seems to have given an instance when he says, "Plans showed 6-in. hard pine sheeting driven to a depth of minus 20, and specifications said simply sheet piling shall be driven as shown on plans." In this case, apparently, the engineer was not authorized to make any changes and the owner held the contractor to the requirements of the contract.

In the writer's own experience the authority to make changes has benefited the contractor more frequently than it has injured him, because the modifications of plans have generally been such as to facilitate construction. If a contractor were required to conform to the terms of an explicit contract I think he would soon be glad to return to a form of contract in which the engineer could use some discretion.

Mr. John L. Howard. — In this paper the author has presented the contractor's side of contract work in a very able and comprehensive manner, and doubtless it will do engineers no harm to occasionally "see themselves as others see them."

During the last twelve years it has been the fortune of the writer to be placed as engineer in charge of construction for various public works in this vicinity. During that time, of course, he has come in contact with all kinds of contractors, "good, bad and indifferent." As a rule, however, he has found that practically all of them were desirous of doing good work, and when it could be done without suffering any loss financially, there was very little friction between the engineer and contractor.

The author claims upon the ground of mutuality in a contract that it is the duty of the engineer to guarantee the correctness and reliability of all borings taken under his direction prior to the letting of the contract. It seems to the writer that contractors have no basis for making this claim if the borings are made by a firm accustomed to that kind of work, and if the different samples are properly located and labeled, and the contractor is at liberty to examine them for himself any time before his bid is submitted. When this is done, hasn't all been done that any reasonable contractor has a right to expect? In such case the contractor has all the data that the engineer possesses, and in case it develops during the prosecution of the work that the materials passed through are different from those indicated by the borings, isn't that one of the legitimate risks which a contractor expects to assume in undertaking work below the surface of the ground?

Then the author objects to the clause "or as otherwise directed" in connection with work which he is required to do, but in large public works extending over a number of years it is almost inevitable that changes will be required, either by acts of the legislature or by orders of the city councils, and it seems no more than reasonable that the engineer should write his specifications with these contingencies in view.

In his comments on the requirements in specifications, the author objects to having a certain percentage of sand pass a certain number of sieve when the words in the specifications only call for "clean, sharp sand"; but where gravel is passed over screens having 0.5-in. clear openings, oftentimes the result obtained gives more nearly a good quality of roofing gravel than sand suitable for concrete.

Several of the phrases to which the author takes exception in specifications are very similar to the specifications for work under the writer's direction. In the clause "timber attached to the masonry," where the contractor is required to embed in or attach to the masonry sills and bearing timbers and such other timbers as may be required, the author apparently objects to classifying frames for tide-gates under the head of "timber," but a little farther on in the specifications it is specifically mentioned that bearing timbers for the tide-gates and sluice-gates were included in this item, and the writer fails to see where wooden frames bolted together are any the less timber for that reason.

Regarding masonry joints, the author quotes three instances where it appears that a wide joint has given better results than a thin one, and further on says, "We can't ask you to discharge your inspectors and take everything that comes, but we can and do ask for *reasonable inspection;* . . . but when work goes out of sight, or under ground, or under the sea, a pea-green stone is as good as cadet gray, and a $\frac{7}{8}$-in. joint as good as $\frac{3}{8}$-in."

The words "reasonable inspection" are liable to be interpreted quite differently by different people. To the engineer they might mean compliance with the specifications as written, and if the engineer called for $\frac{1}{2}$-in. joints over all the work, whether under ground, under the sea, or in plain sight, why shouldn't he have them? On the other hand, to the contractor they might mean that the specifications should be carried out to the letter only when the work in question is in some exposed place where the general public would view it plainly each day, but that where the work was out of sight, something not quite so

good, perhaps only in appearance, although just as solid, ought to be allowed. Now every engineer on any large work always allows some divergence from the specifications in small matters not affecting the stability or permanence of the work, but they seldom get any credit for doing so from the contractor, and if the engineer tries to enforce the letter of the specifications in particular cases where it seems to be essential, he is often met with the cry of exacting " the pound of flesh."

It seems to the writer that allowing variations from the specifications is a dangerous custom, causing constant friction between the engineer and contractor, because if it is done once, why can't it be done again and again, and of course it is not fair to the other bidders who perhaps put their prices high enough to cover the cost of the work as called for in the specifications and possibly by that means brought their total so high that they failed to get the contract.

It seems to the writer that this whole question is largely due to the practice of contractors bidding for work under certain specifications with the expectation that if the contract is awarded to them, they will be allowed to do the work in their own customary manner. A large number of them seem to act as if the various clauses, which say that the engineer shall be the authority to decide as to the meaning and intent of the specifications, as to the manner in which the work is to be done, and that the work is to be done to his satisfaction, should read that the contractor is to be the one who will decide as to the meaning of the specifications, and to decide as to the way and manner in which the work is to be done, etc. And it seems to the writer that all of these troubles will be largely obviated if the contractors, upon signing a contract, will make up their minds to comply with the specifications as printed and not attempt to substitute others of their own.

Mr. Alfred D. Flinn. — Mr. James W. Rollins, Jr.'s paper is particularly timely and suggestive to the engineers of the Board of Water Supply of the city of New York, who are just preparing the first large contracts for one of the greatest engineering projects of the times. With many of the criticisms of recent contract practice the writer heartily concurs, but it seems that the author tacitly, at least, assumes a righteous and capable contractor. Such a one, we regret to say, is not always the " party of the second part." The engineers and the legal counsel for a municipality or a corporation must guard against the irresponsible and unprincipled as well as the incompetent bidder,

especially in public lettings in which the lowest bidder must receive the award. Hence, contracts and specifications must be drawn, in the majority of such cases, to provide for dealing with the worst man or organization rather than the best by whom the work may be done.

The difficulty just mentioned has been obviated to some degree by giving to public officials, and by reserving in the advertisements for proposals, the right to award the contract to the bidder whose bid, all things considered, is for the best interests of the municipality or corporation. This puts considerable responsibility upon the chief engineer, as it usually falls upon him to investigate the bidders and report, with recommendations, to his principals. If this power be abused, there is danger of discouraging competitive bidding, and, therefore, unless there is very good reason, contracts should not be awarded to other than the lowest bidder. Opportunity, however, is provided for avoiding the exceedingly undesirable contractor who, under the rigid method of awarding to the lowest bidder, becomes a great trial to the engineer by performing the work unsatisfactorily and possibly at considerable loss to both parties.

In passing, it may be noted that in some places "extra work" clauses are not permitted in public contracts. In such cases apparently the only method for doing additional or extra work is by subsidiary agreement. In some instances, if the cost of such work exceeds a certain relatively small amount, bids must be obtained.

Burdensome requirements and uncertainties in contracts and specifications increase the cost of work and are, therefore, ultimately borne by the owner, the "party of the first part." In any specific case a part of the cost may fall upon the contractor, but if the contractor is to remain in business he must recoup himself for all his costs and make a living profit besides. Fair contracts and reasonable specifications are to the owner's advantage. It is well to remember that the bid price, if a lump sum, or the amount determined by the preliminary quantities and the unit prices bid, does not always represent the total cost of the work, and sometimes misleads the owner or the public official, because through incompleteness or unfairness of the specifications the work is underestimated by the contractor, and bills for extras and other claims materially increase the first figure. The fairer and more complete the specifications and the information furnished the bidders, the more nearly should the bid price approximate the actual final cost.

Engineering is exact only in part, even theoretically. Conditions of construction of civil engineering works involve many uncertainties, especially in long-time contracts for works of great magnitude. Advancement of the arts, improvement of materials, changes in labor conditions and legislation, fluctuations of financial markets and the development of unknown natural elements of the work, all contribute to the uncertainty. These cannot be absolutely predicted, and in some cases hardly approximated in contracts covering a period of years. Therefore contracts and specifications for such works must be sufficiently flexible to meet changing conditions with fairness to both parties. Many questions and emergencies will arise demanding decision by some one in authority with intimate knowledge of the work, and as yet there seems to be no one better qualified than the engineer.

Some evidence has come to almost every engineer with even limited experience in construction work that some contractors bid carelessly, without due consideration of the drawings, specifications and data furnished by the engineers, and without proper examination of the site of the work. It costs money and time to bid intelligently, but bids for important works should not be presented otherwise. This expense might be regarded something as advertising in other lines of business, as one of the legitimate and unavoidable general expenses to be spread over all the business. The actual advertising of the work and many similar expenses are borne directly by the party of the first part, and, of course, ultimately, the indirect expense of preparing bids likewise comes upon the owner.

Contractors, too, have a proneness to take advantage of all chances for extras, and to make many claims for which there is slight foundation. Furthermore, they sometimes fail to comprehend the real purpose and necessities of the work upon which they are engaged. Hence, there is something to be said on the side of the engineer, as the exercise of patience is not wholly on the part of the contractor.

Mr. Rollins objects to the clause frequently found in specifications that inspection shall not relieve the contractor, etc., and that faulty work which has passed inspection may still be rejected. In this connection it is well to bear in mind that inspectors are sometimes bribed or otherwise influenced by unscrupulous contractors, and there is, therefore, need for the provision just quoted. Furthermore, some forms of deception which are practiced in construction, perhaps without any knowl-

edge, and even contrary to the orders of the contractor himself, are not readily detected at first, and hence pass first inspection, but become apparent later. It seems to the writer that this clause does not interfere with the mutuality of the contract, as both parties are assumed to be working to accomplish good results.

Exactness of specifications is desirable so far as feasible, and there is room for much improvement in this line, but the writer believes that steady progress is being made by engineers in this direction. Lack of exactness is caused, as the author suggests, frequently by lack of definite knowledge on the part of the engineer. This is due not infrequently to the fact than an engineer has to cover a wide range of work in the specifications for a large project, and some of the details are relatively so minor that he cannot afford to get exact information in advance. Possibly too much is passed superficially in this way. Lack of suitable standards of excellence seems to be another reason for lack of definiteness in specifications. At times this lack is very hard to supply, especially if the character of the work is different from any which has been performed in the same locality previously.

A contract having been signed, the engineer and contractor should be on friendly terms and work together amicably for the accomplishment of the substantial intent of the specifications. The engineer frequently has power to aid the contractor without in any way being disloyal to his employer or sacrificing the quality of the work. It is only fair to give the contractor the benefit, in such cases, especially if he is in straits through no fault of his own. Over-rigid interpretations of specifications are generally due to the cautiousness of a young engineer whose judgment has not been seasoned by experience, or by the unseemly assumption of authority by a subordinate who really has but little. Such cases must be dealt with by the chief engineer. Engineers and contractors should work together to rid contracts from the unfair and hard clauses introduced largely by timid legal minds, over-anxious for the day of defense in court and totally ignorant of the nature of the work and of the character of the men who "do things" instead of split words. The lawyer, or some of his kind, is a necessary and good friend, but he needs to be brought into closer contact with rock and dirt and concrete, to hear the chug-chug of the drill, the hiss of compressed air and feel the drip of water down the back of his neck as he descends a shaft.

It seems to the writer that little is to be gained by making

other than the engineer the referee under a contract for engineering work. Occasional unjust engineers there may be, but the unjust are to be found among judges also, and among referees of all kinds. An outsider cannot have the intimate knowledge necessary to a fair decision, and time must be lost in informing any such referee or committee of referees chosen to arbitrate. It does not seem boastful to say that, as a class, engineers are fair-minded men. Indeed, the responsibilities which fall upon the chief engineer or his immediate subordinates for any large engineering undertaking, and the whole course of an engineer's training, tend to cultivate honesty and fairness of mind.

Experience and observation lead the writer to believe that the engineer should rarely dictate the methods or plant to be used by a contractor. Occasionally this may be very desirable. When an engineer does thus dictate, it would seem only fair for the contractor to be relieved of the share of responsibility which does not rightly belong to him.

Finally, in discussing any such subject as this, one should continually keep in mind the difference between large works and small, between short-time and long-time contracts, between public and private conditions and between advertised lettings and lettings limited by invitation to selected parties.

Mr. J. Parker Snow. — I agree with the author of the paper in his objection to the one-sided nature of many specifications and contracts. A large part of the trouble, however, voiced by this paper is due to the inherent evils of competitive bidding.

The altruistic ideal of contract work is for a single competent party to make a price that under expected conditions will repay him his capital with interest and a just profit; the owner to pay for unforeseen difficulties that may arise. This is the man-to-man method of our author. But under the present régime, with king Business in the saddle, and every one, owner, engineer and contractor striving for a place ahead, altruism is hopelessly distanced and conditions are far from ideal.

It used to be said that competition was the life of trade; but competitive bidding between our present-day sharp-lined men of affairs is the death of contracting. In their efforts to cut one another's throats they bleed themselves to death. The struggle naturally leads to combination or bankruptcy. It is warfare between individuals, and this was decreed unfashionable when mankind emerged from the stone age.

However, competitive bidding is still with us and must be regulated by specifications and contracts, sealed and unsealed. One bidder among the many will become the contractor and must execute the work under the inspector's criticisms and the engineer's interpretations, and the owner must pay for all. The dreary mill goes round and will continue to grind out profits and losses for the contractors, salaries for the inspectors and engineers and magnificent constructions for the world at large. A better way than competitive bidding will some day be devised, but it behooves us here to try to ascertain what is best in specification and contract writing.

The two essential elements of an agreement between an owner and a contractor for executing work are the plans and specifications. To these may or may not be added a contract.

The plans should show the dimensions, location and details of the work as far as graphics can properly do so. Notes enough to describe particular features should be added, but, speaking broadly, the plans should contain but few written directions.

The specifications are the real meeting ground between the contractor and the owner or his agent. They should show the conditions surrounding the execution of the work, the classification under which it is to be paid for, detailed descriptions of its several items, the quality of its materials and the class of its workmanship. It is the book of reference for the contractor's foreman and the inspector or owner's agent. If it is clear and complete, misunderstandings will rarely arise; if ambiguous or incomplete, the bid is a gamble and the execution a struggle for "points" between the contractor and the inspector.

"Or as directed by the engineer" is a phrase that seems unavoidable in some instances in specifications. But it should be used as sparingly as possible, for it is a confession of inability on the part of the engineer to define what he wants done, and is a manifest invitation to the bidder to gamble on uncertainties.

The fundamental principle to be borne in mind in writing specifications and in interpreting them is the essence of the square deal and the Golden Rule. And something must be left to the spirit of this essence, for it is well recognized that specifications cannot be drawn to be foolproof, and it is nearly as difficult to make them rogueproof.

A contract, if one is demanded, may well be simple. A signed statement that "I, John Smith, for certain considerations, agree to do certain work for John Doe, according to certain plans and specifications, and to his entire satisfaction" covers

the whole ground, and no amount of phrasing will make it stronger.

These three elements of the agreement, viz., plans, specifications and contract, should be coöperative, but neither should repeat what the other contains. Each has its essential field and should be restricted to it. The whole reason to be of these documents and the feature of supreme importance in them is a clear and precise exposition of the understanding between the interested parties of the exact nature and extent of the work to be done.

Our author has made a plea for fair play on the part of engineers and inspectors. He should not expect this unless he is willing to reciprocate. The contractor who pretends to be in doubt as to whether a uniform color was intended of all the stones in a piece of masonry or simply for each stone so that a speckled hen effect would obtain, when the specification read, "The stone used in the work . . . shall be uniform in color," deserves to have to furnish mosquito frames by board measure and have the mitered corners deducted at that. Speckled masonry may be as strong as any other, but sometimes other features than strength are essential.

If conditions arise that neither the engineer nor contractor could foresee, the former is a Shylock, not fit for his profession, if he will not help the latter as much as his loyalty to the owner and the regulations of his superiors will admit. On the other hand, the contractor who searches for loopholes to dodge the true intent of the agreement deserves all the penalties and adverse judgments that the courts hand down to him.

Competitive bidding is the mother of a large family of expedients, good and bad, for cheapening construction, as well as a bat-winged brood of base attempts to dodge the true intent as above. Until we can supplant the wretched wench with some fair goddess of justice who will handle the scales so that fair play shall be to the interest of all parties concerned, let us of the engineering ilk make our drawings clear and correct, our specifications full and definite and our contracts short and free from one-sided attempts at making law. Let bidders name a fair price for each and all items of work without banking on unbalanced estimates or strained constructions of obscure points. Above all, let bidders abstain from attempting to freeze out or cut the throats of rival bidders. Let contractors execute the work in a spirit of willingness to do what they bid to do, and let owners allow sufficient time for working out details before bidders are called upon the scene.

Engineers, when writing specifications, will welcome hints from contractors, with a view to clearness and smooth working, and I for one am obliged to the author for bringing out the points set forth in his paper. When civilization shall have advanced so that competitive bidding is history, a part of our present difficulties will have disappeared.

Mr. Leonard C. Wason. — The writer has read Mr. Rollins's paper with a great deal of interest and indorses all that he says. As the company with which the writer is connected does a different class of work from Mr. Rollins's they have had some different experiences, which may be of general interest.

As it is generally known that the members of the writer's company are capable of designing any reinforced concrete structure that is built, many owners come to us for designs in order to save the engineer's [commission. The word "owner" is here used to mean the party who pays the bill, whether it be a private individual, company, city, town, state or nation. With the exception of work simple enough for any one to design, it is the policy of the company to advise the owner to employ an engineer or architect, to pay him his full commission and to make him earn it, and to illustrate the various ways an engineer will earn his commission by saving the owner expense that would be incurred if he attempted to do his own work. This is merely stated to show the attitude of the writer towards the work of engineers and architects, and that the criticism which may be offered is in the spirit of the old phrase, "The world may flatter, but it is your friend who tells you your faults."

In the writer's opinion it is very frequently the fault of the *owner* that unfair articles are inserted in contracts. In some cases he does not pay a full commission and the engineer, therefore, will not go to the expense of finding out and assuming responsibility for the accuracy of borings or other uncertainties encountered. A few engineers throw responsibility for all uncertainties to be encountered upon the contractor to save themselves the trouble of the careful study necessary to determine the exact conditions. Sometimes an owner does not allow an engineer sufficient time to do his work thoroughly, and therefore he is compelled to resort to phraseology of contracts which relieves him of all of his own responsibility and requires the contractor to assume it.

Engineers in the permanent employ of an owner are liable to become biased — it may be unconsciously, but nevertheless certainly — from long continuation in one line of service, and they look and act from the viewpoint of the owner rather than

from that of a disinterested referee between the owner and the contractor. Public works departments of cities, states and the United States and the railroads employ a permanent staff, and it is the writer's experience that the contracts and specifications from these sources are subject to criticism most generally, and that there is little criticism to be found with the work emanating from private sources. The chief engineer too often takes the word of an inspector without verifying his statements and without question, and decides a point upon this report, and to maintain a system indorses the report of the inspector, even though later it is found to be wrong. Too frequently inspectors are novices, it being their first employment at engineering, and they are for this reason many times incompetent. Occasionally a thoroughly competent one finds the work carried on satisfactorily, and because he makes no criticism to his chief, it is assumed that he is not doing his duty and he is transferred, or he is ordered to find fault where no fault exists. There is something wrong in the viewpoint of the chief engineer who holds such a view. A competent and honest inspector is a real aid to a contractor.

The writer has largely withdrawn from public work on account of unfairness encountered not only in contracts and specifications, but in the system of administrating them, and because this system has brought into this line of work a class of contractors who are plungers and who gamble on conditions, cut prices and skin the work when they can. Under such conditions it is hard to get a fair price for the work. One-sided, unfair contracts foster this class of contractors, while fair and mutual ones will bring forth a better, honorable and honest class in larger numbers. The position taken by a number of first-class contractors before bidding on a given piece of work is first to see if the work in itself is desirable, then to read the contract and specifications, consider the personal equation of the engineer in charge, whether he is reasonable or unfair, and then figure or decline to figure as the case may be.

The fact that no contractor ever becomes rich proves that the average of all work is done cheaply. To literally fulfill some contracts and specifications the contractor ought to know more than the engineer and to have made a more thorough investigation than the engineer has before he puts in his figure. In the short period of time allowed for making up a bid, it is never possible to completely review the engineer's work to see whether it is right or wrong, even though the contractor has the technical

ability to do so; nor should he be asked to spend the time and money necessary to do this when bidding in competition.

It would be a distinct advance if owners as a class could be made to realize that there is *positively nothing* which raises a bid like asking a contractor to assume *uncertainties* which may be encountered, and that the engineer earns his money by eliminating such uncertainties, thereby reducing the cost probably more than his own commission amounts to and perhaps several times over; and secondly, that by eliminating all unfair and unreasonable clauses a much better class of bidders can be obtained; thus good workmanship can be secured and usually at a lower price than can be obtained from the cheaper class of workmen who gamble on the uncertainties. Insufficient time to prepare a careful bid is the next most important item in raising the cost of work.

The engineer tries to please his owner and frequently is obliged to do things he does not himself approve, but when the owner realizes it is for his own financial benefit to be fair, there will be little fault to be found with the engineers by the contracting fraternity. Let the owner assume all uncertainties. If difficulties arise, he pays the price he would pay anyway, and if they do not arise he wins this amount instead of the contractor. This method implies percentage or lump-sum profit work on the uncertain items, but he has the safeguard of having to pay only once for having his work done right. If the work is not done right the first time, or if carelessly or negligently handled, the owner is no more subject to pay the price of making the work right than if it was done on the ordinary lump-sum contract basis. When the uncertainties Mr. Rollins enumerates are eliminated, there will be a different and better class of contractors and a larger number of them can be found to undertake work; thus there never need be any danger of lack of competition or of an incompetent or negligent contractor obtaining the contract. The owner and contractor ought to become acquainted and friendly; thereby trouble may be smoothed away to the mutual satisfaction of both sides.

Mr. Rollins, in closing his paper, alludes to the courts being left for the Boston Elevated cases. In this connection the writer would like to call attention to one clause from a Boston Elevated contract for desirable work on which he declined to estimate because, in his opinion, it was an invitation to trouble.

It is well known that the Boston Elevated and other large corporations are held up for blackmail and are sued for causes

just and unjust. This clause, which is as follows, endeavors to shoulder on to the contractor trouble which may be real or only *alleged* to be real: " In case any claim is made against the railway company, which claim is based upon, grows out of, or is *alleged* to grow out of, anything done in reference to matters contained in or incident to this contract, the railway company may retain such sums as in the judgment of its president will indemnify it against any loss "; and further, " In addition to damages indicated above, may deduct reasonable charges incident to the investigation and defense of such claims." It is impossible for the contractor to allow for this contingency in advance adequately, and to make an allowance for a contingency that may not arise would require the railway company to pay more for the work than it need to. Labor leaders would have no better weapon than this for attacking the contractor. They could trump up a claim, press it with vigor and in this way hold up money and put the contractor to considerable expense for which he was in no way legally to blame. Allowing the railway company to settle the case at his expense, including the costs, without consultation, thus permitting a party who is not financially interested in the expense to become your attorney in fact with full powers is a usurpation of justice which the writer is unwilling to grant. This same contract also requires the contractor to guarantee the sufficiency of the engineer's plans and specifications in all particulars.

It is hoped that all contractors will protest against contracts of this nature. Those who will not are deserving of all the trouble that can come to them.

Mr. James W. Rollins, Jr. — After careful study of the discussions, it seems that many of those members participating agree upon most of the principles in the original paper.

Some admit that the claims are all right for honest contractors, but contend that to protect themselves engineers must make a contract and specification for a dishonest one. Almost every contract for public work provides " that the work shall be let only to bidders who can furnish satisfactory evidence that they have the ability and experience to do the class of work called for, and that they have sufficient capital and plant to enable them to do the work successfully and to complete it within the time named in the contract." Why isn't this clause protection enough for any engineer, and sufficient ground for him to reject the bid of any dishonest or incapable contractor and let a good one have the work? Most contractors must com-

pete for work; few get to be so honest and reliable that they can live on contracts which they "select as desirable." We have some ambition at times to bid on public works, and we know we must bid against everybody, good, bad and indifferent, and almost always with the knowledge that we can't get the work unless we are the lowest bidders.

We contractors also know perfectly well that the personality of the engineer can make or break us, and the writer leaves out in this statement any question of actual honesty or dishonesty; that is, in plain words, if an engineer demands in full every and all conditions of the specification to be carried out the job is a failure financially. Opinions are expressed in the discussions that such a contractor should fail, that he has agreed to do certain work and that he should be made to do it, made to do *perfect* work. Are engineers *perfect?* Can perfection be obtained in many things — in any thing? Perfection is *exact* compliance with specifications; but may I ask, Is the work better or stronger because a joint is *exactly* ½-in. or the color is the exact shade called for, especially as most masonry is discolored in six months after being laid? But as long as we have engineers we shall have the *exact* ones, who will have their pearl gray color and their ½-in. joints, their measurements to a thousandth, with perhaps their feet wrong. They are surely the "stewards" who will get their 100 cents on a dollar and the pound of white sugar they ask for; and what else? — a reputation among contractors, and the honest ones too, so that after having been "led once to the slaughter" they refuse to bid on any more work to be done under such engineers, or bid so high that they will not get the work. The writer knows of such engineers — perfectly honest but not just and fair — men for whom contractors will not work at any price, and whose reputation even among their fellow-engineers and their superiors is that of a "*grandma.*" Cannot you engineers in charge of work train up your young men to use their judgment, to be free to treat contractors fairly, get good, true, honest work without fussing at some trivial lack in detail which amounts to nothing, but to correct which means loss of time, money and patience; to work in harmony for the best of everybody?

Certain engineers seem called upon to assume all responsibility of *design* of temporary work, and then disclaim responsibility in results. Hasn't the time about come for such men to realize that among the contractors are engineers who know their own business, and who knowing it will be thoroughly able

to protect their own interests; or who, if they are not themselves technical men, are good enough business men to get an engineer to figure out for them anything necessary? Why is it necessary to furnish plans of centering, ventilation, etc., of tunnels, which matters, in the judgment of the writer, can best be provided for by the contractors, who make such work a specialty, all done upon the ground of safety to men; and leave out of their plans the handling of explosives? As far as the writer has knowledge, the underground work in the New York subways and tunnels, in the Pennsylvania Railroad work, also the subway work in Boston, has all been done by the contractors — they making their own plans of temporary work and being responsible therefor. In the years of work done by the writer on railroads, where certainly the danger of loss of life is greatest, the railroad engineers do not pretend to say how a contractor shall do his work, in its temporary nature. Any engineer has every right to stop a contractor when he goes wrong; so why entail a lot of ill-feeling, disputes and trouble, and also do a great injustice, by prescribing all details of temporary work, and then holding contractor responsible for it, design and all? *It's not a square deal;* we contractors can stand on our own feet, do what is necessary, and be responsible for it.

Mention is made that never does an engineer know what he wants when the contract is let. How then does he expect the contractor to make an intelligent bid? — for if the engineer doesn't know, the contractor surely doesn't. It is admitted that plans cannot be perfected in a short time, but surely an engineer should know what kind of cement he wants as to chemical analyses; what kind of sand he wants as to size; what size piles he wants, and all such matter, when he writes the specifications. As to plans being perfected before contract is signed, the writer recalls two large contracts executed by his company, almost adjoining, and built under almost exactly the same conditions. On one contract plans were made in detail and a lump sum price submitted, and so well did the engineers do their work that on a contract of $600 000 there was never a charge for extra work on account of any error of plan, nor any row with engineers over meaning of plans or specifications. On the other job, work was let by items, on a general plan. When the detail plans came out, in many places most expensive forms were needed; concrete shown in massive walls was changed and built full of economy holes; then walls were built with steel reinforcement, that is, steel concrete was substituted for ordinary concrete, at the

latter's price. We all expect changes, and that such are necessary; but we do not expect, and we do object to, changes such as mentioned, made to save money for owners, and cost *us* money to execute. When such changes come, discussions, disputes and bad feelings arise, and unless the engineer is fair enough to admit the value of such changes and pay for them a loss falls to the contractor. This experience has led the writer to always favor a lump sum contract.

The writer still sticks to the dictionary as to what timber is — *a single stick of wood;* and a *frame* is made of *timbers* fastened together.

Comment is made on the " as otherwise directed " clause; and by one member to the effect that such a clause is necessary because the legislature or city council may order changes, and that the engineer should have that in mind — to do what? — *to be able by law* to cause the *contractor* loss, with no redress?

One member states that we criticise existing affairs and offer no remedy. We do offer a remedy, and in two words: give us a " square deal."

When engineers draw up a contract — and if they don't draw it up they are responsible for it — with the words " do the work and the whole thereof " — words which mean little to a contractor amongst the great mass of words in a contract, but which may mean under the courts' decision the loss of everything he owns, and because an engineer *didn't know his business* and design his work well — it seems to the writer a gross act of injustice and a great wrong; it is the act of some weak, cowardly mind, who does not dare to stand by his own work and take the honor or blame as either may come.

The writer proposed to bar six stipulations; and, to emphasize the matter, will repeat them:

First. Disclaiming responsibility for soundings or other information as to the character of the work.

Second. The insertion of clauses which make any contractor's estimates worthless by adding, " or as otherwise directed."

Third. Making the contractor responsible for work for which engineers make the plans or require their approval to any made by contractor, and where engineers reserve the right to entirely control the manner and means of construction.

Fourth. Holding contractor responsible for work which has passed inspection or has been done under direction of engineer, or his agent, or inspector, unless fraud can be proved.

Fifth. Making the engineer the sole referee in settling all claims.

Sixth. The right to stop work, or any part of it, if for the interests of the company so to do, without allowing the contractor anything for the loss such action might bring to him.

With these eliminated from contracts, with specifications explicit in defining qualities of material wanted; and with a fair interpretation of such specifications, having in mind the source of supply and the work in hand; then, in the opinion of the writer, we shall have the "*square deal*" we ask for.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1907, for publication in a subsequent number of the JOURNAL.]

ANNUAL ADDRESS.

The Engineers' Club in Its Relation to the Future St. Louis.

By W. A. Layman, President of the Engineers' Club of St. Louis.

[Read before the Club, December 19, 1906.]

Gentlemen of the Engineers' Club, — It has been the custom for the retiring President to present to the Club at this time a brief paper discussing the general welfare of our organization in some important respect. I have therefore selected as my theme to-night, "The Engineers' Club and its Relation to the Future St. Louis."

This Club has been an institution justifying by its long record of conservative engineering discussion the public confidence which it evidently receives. Its members have comprised throughout its existence substantially all the leading engineers of the community irrespective of their individual lines of professional demarkation. It is to-day in healthful, vigorous condition promising even greater usefulness to its membership and the community at large than has existed in the past. We may with propriety entertain no small degree of pride in the record we have made as a Club, steering our course so as to avoid contamination from political and social influences and maintaining an engineering integrity unusual in degree.

In looking back over this record of the past, seeking to balance up the achievements of the Club against its possible opportunities for good, I have been deeply impressed with the evidence of wisdom shown in its creation, and in its direction over a period of thirty-eight active years. I trust we may move forward with few deviations from that course of careful conservative public and professional policy which has been the secret of our success.

I have therefore turned my eyes from a criticism of the past to a contemplation of the future, seeking to discover wherein we may be of greater value to ourselves and to the community in which we live. At a recent meeting of the Club our subject for discussion involved a review of the work accomplished by the Mayor's commission on the study of the terminal situation. One of our speakers tersely remarked that in his

opinion the Engineers' Club was getting into the field a little late, implying that we could have served a better purpose had we taken a creative rather than a retrospective interest in this terminal situation. I deem this comment pregnant with suggestion for the Club. We, with numerous other organizations in the city of St. Louis, are looking forward to a time when our city will have, not a population of one million as some of our enthusiastic citizens are talking so much about, but instead a population of two millions, and rapidly thereafter larger and larger numbers. Why may not this Club, with wisdom and propriety, give itself seriously to the contemplation of such an era of civic expansion? It is essentially the business of the engineer to serve the public constructively. Individually, we live in a constant atmosphere of creative work. Why may we not collectively and as a Club take on this same relation to the general public? I offer the suggestion that we seriously give ourselves as a Club to the study of the needs of the St. Louis of 1925. There are several reasons justifying such a policy on our part, some of which I may briefly recite:

St. Louis as a city of two millions population must undergo a physical metamorphosis involving problems of engineering character of very great importance. We are face to face now with the consideration of such questions as a rapid development of water supply; a sane and economic disposition of garbage and sewage; the evolution of a system of rapid transit; the large expansion and reorganization of our general system of passenger and freight railway terminals; the evolution of a general scheme of beautification for our city; a reconstruction of our ideas bearing upon the wagon transfer of merchandise, as well as pleasure and business travel by carriage; the creation of some underground means of transportation for both passenger and freight. These topics are the suggestion of present current discussion. It is difficult to predict the further important problems of an engineering character which will be developed by the process of rapid evolution through which our present generation is passing.

It is pre-eminently the business of the engineer to link the facilities and conditions of the present with the requirements of the future. Therefore the people of St. Louis will in the near future, even more than at present, be pressing upon us as engineers the solution of the questions herein involved. I say they will be pressing upon "us," meaning by "us" the membership of this organization. I should qualify this by saying they will be pressing the solution either upon us or upon *other* engineers non-

resident in the city of St. Louis. We *think* we are here to do all this work for the city of St. Louis; we *hope* to do it. What is the best manner of proceeding, therefore, to secure to ourselves the doing of all these great tasks from which we may expect engineering and financial remuneration commensurate with the service performed? I offer the suggestion that this may be accomplished by constituting the Engineers' Club of St. Louis a forum wherein to seriously study and discuss these questions of our future public needs. Let us assume a creative phase for our Club work; let us select standing committees, the functions of which will be the study of specific phases of the future engineering conditions of the city of St. Louis. Let us have committees on rapid transit; expansion of terminals; beautification of the city and other lines of public need hereinbefore alluded to, and let us impose upon these committees the definite and immediate task of taking up the study of the requirements of the prospective city of St. Louis with the purpose of reporting back to the Club annually, or at more frequent intervals, if desirable, a general discussion of the questions particularly assigned to them.

It may be asked whether this is not encroaching upon the private responsibilities of the individual engineer. I think not. Every progressive engineer is naturally developing himself along some particular line, but in his individual field he has small opportunity to impress public sentiment with the views he may individually entertain. With all these topics it is essential to bring the public into a realization of what the city will eventually require. This could be done in a peculiarly effective way through the medium of an organization such as ours, the reputation of which, for conservatism, has been established by a record of thirty-five years. It may further be asked if this is not asking a measure of self-sacrifice on the part of our busy individual members going beyond the reasonable demands of our Club organization. I do not think so. Our leading engineers must study all these questions carefully and continuously if they expect to do the engineering work for the city of St. Louis. Why not give the fruits of this study to the public by a progressive presentation of the results arrived at through the medium of our Club meetings? It will then be realized by the public that in the city of St. Louis there are engineers who have their minds and talents concentrated upon these questions, men who know what has been done elsewhere and therefore men who are competent to attack actual solution of these local problems when the time arrives for the municipality to take them in hand.

There have been occasions in the past when important civic commissions have been partly, if not fully, made up of engineering talent called from outside the city of St. Louis. There will be occasions in the future, if our own engineers continue silent on all these questions of public interest, when eminent engineers from elsewhere will be invited to do these prospective important tasks. Let us prevent this by having our Club become a non-partisan factor in a consideration of these future needs. Let us freely give, through the Club, from time to time, the information we have at hand, and the views we have formulated as to our public needs. Let us conduct a program of individual education through the medium of work for our Club. Gentlemen, you see now what I mean by my subject, "The Engineers' Club and its Relation to Future St. Louis." I do not invite a departure from a policy of conservatism; I rather invite a campaign of creative *work* — a reward for which may be eventually disclosed in the acceptance by the public of comprehensive schemes of engineering works proposed for the city of St. Louis by the Engineers' Club of St. Louis, and executed by the individual resident engineers of the city of St. Louis.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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COMPARATIVE RÉSUMÉ OF THE SEWAGE PURIFICATION TESTS AT COLUMBUS, OHIO.

BY GEORGE W. FULLER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Sanitary Section, December 6, 1905.]

ON December 6, 1905, the writer had the pleasure of giving an informal talk before the Sanitary Section of the Boston Society of Civil Engineers on the results obtained from a quite extensive series of sewage purification tests conducted at Columbus, Ohio, for about one year under the immediate charge of Mr. George A. Johnson. These tests formed a part of an elaborate series of studies made to aid in improving the municipal works of Columbus as projected by Mr. Julian Griggs, chief engineer, and now being executed under the direction of Mr. Henry Maetzel, chief engineer since March 1, 1906, and Mr. John H. Gregory, engineer in charge.

At the time that the informal talk was given, the detailed report of Mr. Johnson on these sewage tests was in press. With the appearance of this report in April, 1906, the need of editing the stenographic notes of this talk largely disappeared. However, it has been thought that it might be useful if some of the writer's notes upon this subject were put in shape so as to show in a comparative way those features where there were discrepancies between or confirmation of the Columbus experiences and those elsewhere.

On behalf of Hering and Fuller, consulting engineers on the new works at Columbus, the writer took active supervision of these sewage tests from the outset, and has had the good fortune

to have discussed the outcome at considerable length with various leading European workers on the occasion of two visits to Europe during the past year. He has also had the benefit of the views of Mr. Johnson who, during the past year, has noted the applicability of the Columbus data to problems in various foreign lands, and who has studied these data in the light of numerous other experiences in this country.

The Columbus Sewage Problem.

Columbus is a city of about 175 000 people. It is situated slightly southwest of the center of Ohio and about 100 miles from Lake Erie. It is upon the upper portion of the watershed of the Scioto River. This river flows nearly due south from Columbus for a distance of about 100 miles, where it enters the Ohio River.

Geologically, Columbus is situated near, but still within, the southern limits of the glacial drift formation. The city is located in a limestone valley, and while there are deposits of coarse sand and gravel in the neighborhood, they are all overlaid with so much clayey and impervious material that it is not possible to obtain locally any natural sand filtration areas such as are so conspicuous in solving purification problems in New England. And, furthermore, those areas of porous sand and gravel which are to be found near Columbus are in most cases very low with reference to the ground water level. The site of the plant which is now being built has, some three or four feet beneath its surface, quite a thick stratum of porous sand, but it is but very slightly above the ordinary water level of the adjoining Scioto River and is entirely out of the question for any practical use in sewage purification.

Hydrographically, the conditions at Columbus are these: The Scioto River is joined by the Olentangy within the city limits. The two streams together have a drainage area of 1 665 sq. miles. The low stream flow is from 30 to 50 cu. ft. per sec., and is noted for many days and weeks at a time. On the basis of $3\frac{1}{3}$ cu. ft. per sec. as a dilution necessary to avoid nuisance from the sewage of a population of 1 000, there would be a permissible limit at such times perhaps of 10 000, as the number which could drain directly into the Scioto River. At times of flood flow the other extreme, of course, is reached for the run-off of that section; and under these conditions the sewage of over a million people could be disposed of without creating any nuisance. During low water the Scioto River is usually unsightly and foul smelling.

To trace briefly the efforts which have been made during the past ten years to solve this problem, it is necessary, first, to mention the report made in 1898 by Mr. Julian Griggs (who was the city engineer of Columbus up to March 1, 1906), and by Mr. John W. Alvord, consulting engineer, of Chicago. These gentlemen made an elaborate report, which treated of the ways by which they could intercept the sewage, collect it at main pumping stations and deliver it to a purification site. As to the method of purification, they recommended screening and filtration through coke, — practically contact filtration as we understand it to-day. They got out preliminary designs for a plant of 20 000 000 gal. daily capacity, and provided 40 acres of coke filters. It was their idea that it would be wise for the city to build about two acres of those filters at first, and then, after testing them for a year, to design the remainder of the plant in accordance with the experience of that first year. The city did not then have funds to consider the matter, and the problem remained in abeyance for about two years. Then a city sewerage commission, under the following administration, took up the subject anew and the city engineer at their request made estimates of a system involving septic treatment and intermittent filtration, the idea then having gathered strength that contact filters would be too expensive.

Following those estimates a scheme was prepared of a temporary nature by which the sewage was to be treated in septic tanks alone. On the plea of economy that project was put before the Ohio State Board of Health in the autumn of 1900 and was disapproved by that board on the ground that there was no evidence to indicate that it would prove suitable or adequate at times of low stream flow. In the spring of 1901, Mr. Rudolph Hering, of New York, was called in consultation, and, after reviewing the local evidence, approved of the plans for interception, pumping stations and other general features, and advised that they build a plant consisting of septic tanks or sedimentation basins, and follow that treatment by intermittent sand filtration through beds of artificial construction, built of material brought from the shores of Lake Erie, some 100 miles distant. He, too, advised that only a portion of this plant be built at first and that the remainder be designed after they had gained practical experience in the use of a portion of the plant for at least a year. This project was approved by the Ohio State Board of Health, subject to some qualifications as to the manner in which the plant should be built in a tentative way,

and also subject to reasonable requests as to care in the manner of operation.

The State Board of Health at that time also stated that they considered the evidence quite limited as to the correct capacity of septic tanks and sand filters under these conditions, and formally advised that the matter be thoroughly investigated before such a large sum of money was expended. The matter from that time remained in abeyance until the autumn of 1903, when, owing to a change in the municipal code of the cities of Ohio, as to their financial means, the people came to vote on the issuing of bonds for improved sewerage. That vote, in November, 1903, for an issue of $1 200 000 for improved sewerage and sewage disposal works, was favorable.

The Columbus Testing Station. — The first step toward carrying out these improvements was a decision on the part of the Board of Public Service, upon the advice of their chief engineer, Mr. Griggs, and consulting engineers, Messrs. Hering and Fuller, and also the State Board of Health, that a testing station be built. The position was taken that the expenditure of a sum of money representing roughly the interest on the capital involved for one year could well be spent and result ultimately in decided economy. Councils passed an ordinance appropriating $46 000 to be devoted to the purpose of a testing station, in which there were to be obtained practical data to show the cheapest and best way of purifying the sewage to the extent necessary under the local conditions.

The station was placed under construction in May, 1904, and its equipment was completed in the following July. It was operated under the charge of Mr. George A. Johnson. The more important details of this station have already been set forth so thoroughly in engineering papers that it is necessary to speak but briefly as to its arrangement. (See *Engineering News*, October 20, 1904, and *Engineering Record*, November 19, 1904.)

In short, this station was designed to purify at least 350 000 gal. of sewage daily, and to test all the well-known methods for preparatory treatment, involving plain sedimentation at low and at high velocities, septic treatment, chemical precipitation and coke strainers. For the final treatment there were twenty-one intermittent filters of sand brought from Lake Erie and in which the sewage, after various preparatory treatments, was treated at different rates, with the special view of making those rates as high as possible under local conditions. In addition to the well-known method of intermittent sand filtration, there

were also filters of coarse material, contact filters and sprinkling filters, which were operated in different ways and with sewage which had received different kinds of preparatory treatment. In all there were about forty-two devices.

Mr. Johnson had on his staff fourteen men, nearly all of whom were technically trained. His inspectors, who read meters, collected samples, etc., were, for the most part, recent graduates in engineering at the local university.

Sampling Schedule. — In the case of the crude sewage, samples were collected at half-hourly intervals throughout the twenty-four hours, and the several portions then mixed for analysis. In order that the sewage of no one day in the week should receive more than its proportional weight in the study of the composition of the crude sewage, a schedule was arranged at the beginning of the tests whereby no samples were collected on every eighth day. The day on which the sewage was not sampled was thus moved forward one day each week, so that no day was omitted from the sampling schedule twice in succession, but only after the lapse of seven weeks.

In the case of the sand filters and the contact filters the hours of dosing were varied throughout the tests in an attempt to cover all conditions. The day on which the sprinkling filters were sampled was moved ahead one day each week.

Amount of Analytical Work. — The number of analyses which were made in connection with carefully gathered engineering data was, perhaps, a little unusual. From a majority of the devices where there was a continuous flow, samples were collected at half-hourly or hourly intervals. Of the raw sewage alone there were 13 536 different portions collected. In round numbers, 9 000 portions were collected of the effluents from the various tanks in which sedimentation played a part. In the case of the effluents from the various sand filters the samples were collected after receiving and carefully mixing the effluents in measuring boxes. Average samples of the influents were collected as the filters were flooded. Samples from the contact filters were collected at weekly intervals near the beginning, middle and end of the emptying period and the several portions mixed in aliquot quantities for analysis. The same procedure was followed in the case of the influents. Bacterial samples were collected at the same time, and the results of the individual analyses were averaged.

In the case of the sprinkling filters samples were systematically collected at weekly intervals. On the sampling day

portions of the influent and effluent were collected at hourly intervals throughout the day, and the 24 portions were then mixed and analyzed. The individual portions were collected in 4-oz. bottles, which were completely filled, tightly stoppered and placed on ice. Bacterial samples were collected from the influents and effluents at 7 A.M., 11 A.M. and 4 P.M., on the regular sampling days, each sample being plated as soon as collected. The results of analysis of the three samples were averaged to give a representative mean.

In all, 3 270 complete chemical analyses were made; 4 356 bacterial analyses; 483 additional analyses for suspended matter and 130 analyses of sludge.

Degree of Purification Required. — At Columbus it was required that the sewage should be purified so as to make it non-putrescible and of a fairly presentable appearance. It is some 200 miles to the intake of the nearest public water supply and while it is not doubted that disease germs in gradually lessened numbers can travel this distance, it is believed that they will only be present in such quantities that their influence will not materially add to the task of purifying the Ohio River water under existing local conditions for some time to come.

As to the quality of the water in the Scioto River below Columbus, the proposed sewage purification works should entirely eliminate all questions of nuisance. It is not expected that in its raw condition this river water, even with the sewage of the city of Columbus eliminated from the Scioto Valley, would be fit for drinking purposes. This is due, of course, to the pollution entering the river from the rural population and a few small towns and villages above Columbus.

It will be seen that this problem differs quite materially from those where shell fish industries are intimately involved, as in the instance of Baltimore, or in the case of the disposal of the sewage of small towns resident upon the drainage area of an unfiltered water supply such, for instance, as Natick, Framingham and Marlboro, Mass., in their relationship to the Sudbury and Cochituate water supplies of Boston.

General Significance of Sewage Tests such as those made at Columbus.

It was the purpose, in solving the Columbus sewage disposal problem, to collect data first which would enable us to learn as definitely as we could what the problem was we had to face, and then the ways and means by which the problem could be solved

at least expense. In many ways the sewage disposal problem of Columbus has been conducted in a somewhat similar manner to the well-known water purification investigations at Louisville, Pittsburg, Cincinnati, New Orleans, etc.

While in some ways it may be said that there was almost nothing new in the devices tested at Columbus as to their applicability under local conditions, it is not out of place here to refer briefly to the fact that this idea of fitting various procedures found satisfactory elsewhere to the actual local conditions of a specific problem has had a great deal to do in advancing the art of water and sewage purification during the past 15 or 20 years. The writer quite recently looked into this subject, and found that investigations upon water and sewage purification projects in this country have been conducted to the extent indicated by the following experiences:

TABLE No. 1.

List of Special Investigations on Water and Sewage Purification.

Place.	Date.	Work.	Approx. Cost.
Lawrence, Mass.	1887 to date	Water & sewage	$175 000
Providence, R. I.	1893–94	Water	5 000
Louisville, Ky.	1895–97	,,	47 395
Reading, Pa.	1897	,,	1 500
Pittsburg, Pa.	1897–98	,,	36 286
Cincinnati, Ohio	1898–99	,,	41 588
West Superior, Wis.	1898–99	,,	2 000
Washington, D. C.	1899–1900	,,	8 000
Richmond, Va.	1900	,,	2 000
New Orleans, La.	1900–01	,,	23 606
Worcester, Mass.	1900 to date	Sewage	37 000
Philadelphia, Pa.	1900–05	Water	172 000
Springfield, Mass.	1901–03	,,	18 000
Harrisburg, Pa.	1903–04	,,	25 000
Mass. Inst. Tech., Boston	1903 to date	Sewage	20 000
Columbus, Ohio	1904–05	Sewage and water	44 004
Waterbury, Conn.	1905 to date	Sewage	10 000
Total			$668 379

In Europe the tests are not, as a rule, conducted in precisely the same way as at Columbus, but they are run side by side with the operation of plants in practice. The same sound process of stepping from the unknown to the known is largely utilized, however, and one of the most gratifying features in the development of sewage disposal problems is the gradual development side by side of the engineering, chemical and biological aspects of this subject.

The Columbus Sewage.

There were two features towards which unusual attention was paid at Columbus. The first of these was to find out what was the composition of the local sewage, and the second was to find out the best means of giving it a preparatory treatment by which the major portion of the suspended matter, or sludge, could be most advantageously removed. The first feature will be taken up here as it is essential for the presentation of the second one.

The testing station was located at the foot of the main intercepting sewer, draining the business portion of the city and a large portion of the manufacturing and residential districts. This main sewerage district has a population of about 100 000, and of that number about 75 000 are connected with the sewers. This intercepting sewer had an average flow of about 9 000 000 gal. daily. It was practically as representative of the future sewage of Columbus as it was then possible to get. The sewage there is not essentially one from a manufacturing community. There are a good many small iron works, foundries and the usual quota of breweries, tanneries, laundries and dye works, but except at times of very dry weather flow there were only short periods at a time when any manufacturing waste made itself very conspicuous at the testing station.

This portion of the sewerage system of Columbus, as should have been already stated, is on the combined plan. Future additions are to be on the separate plan. The public water supply there is very hard, and there is the usual leakage of ground water, perhaps somewhat more than usual in those sections of the city where the sewers pass through porous gravel strata. On the average the sewage represented a strength of about 120 gal. per capita daily. The results of the analyses of the sewage showed that, so far as the weights of each constituent of sewage per capita are concerned, it is very similar to that of London, England. It is much stronger than the sewage of the smaller Massachusetts cities, such as have been reported upon so carefully by the State Board of Health, and it is much more dilute than that of the manufacturing cities, such as Worcester, Mass., and Manchester, Birmingham, Leeds, Huddersfield and other English cities. The amount of suspended matter was about 215 parts per million, about such a sewage as that received at the Lawrence Testing Station in its early days, and about such as is received on the filtration areas at Clinton, Mass. It will not be necessary to record any more

of these details other than to say that it is not so strong a sewage as that at Brockton or some other places where the concentration, of course, is greater than at Columbus. But speaking generally, it may be considered to be a good representative domestic sewage, without unusual manufacturing wastes and with a normal amount of street wash from a clay country.

In Table No. 2 summarized data are presented showing the composition of the Columbus sewage, the various constituents being expressed in grams per capita daily. For the sake of comparison the composition of certain other representative sewages is also given.

In explanation of the data in this table it is to be stated that the records for the Columbus sewage involve the results of the analyses of more than 13 000 portions of sewage collected at frequent intervals during a period of about ten months. The average result approximates a 10 per cent. increase to the constituents found during a period of six weeks' drought, and during which time half-hourly samples of the sewage were collected on seven days of each eight-day period.

TABLE No. 2.

ESTIMATED QUANTITIES OF PRINCIPAL CONSTITUENTS IN GRAMS PER CAPITA DAILY OF THE SEWAGE OF COLUMBUS AND OTHER CITIES.

Constituents.	Average Columbus Sewage. (Combined System.)	Average Domestic Sewage from Small Mass. Cities. (Separate System.)	Average Domestic Sewage and Street Refuse. (London Combined System.)	Average Sewage for Manufacturing Cities. (Combined System.	Estimate Baltimore. (Separate System.)
Oxygen Consumed:					
Total	30	16.6	25	50	25
Dissolved	14	10.0	...	...	10
Suspended	16	77.0	...	...	15
Nitrogen·					
Total	14.4	11.6	13.0	13.0	13
Organic.					
Total	6.2	5.6	5.0	7.5	5.0
Dissolved	2.4	...	...	...	2.0
Suspended	3.8	...	...	...	3.0
Free Ammonia	8.2	6.0	8.0	5.5	8.0
Chlorine	32.0	16.0	24.0	44.0	16.0
Dissolved Matters:					
Total	410	97	157	268	..
Mineral	354	62	102	178	..
Volatile	56	35	55	90	..
Suspended Matters:					
Total	98	53	87	145	90
Mineral	51	12	41	69	35
Volatile	47	41	46	76	55
Total Solid Matters:					
Total	510	150	244	413	..
Mineral	407	74	143	247	..
Volatile	93	76	101	166	..
Free Carbonic Acid	13.6	...	...	...	..
Fats	19.1	...	...	...	19

Outline of Paper. — The writer has had numerous comparisons made of the Columbus data with other results from this country and abroad. Last winter such data were prepared as preliminary to the consideration of essential details of the problem at Baltimore, and more recently they have been reviewed in connection with a report, prepared in the office of the writer, to the International Waterways Commission upon sewage disposal at Chicago and vicinity.

The points presented in this paper are those most suitable for discussion, and are grouped under several headings as follows: I. Preparatory Treatments; II. Synopsis of Septic Treatment; III. Intermittent Sand Filters; IV. Contact Filters; V. Sprinkling Filters; VI. Sedimentation and Filtration of Effluents of Coarse Grain Filters; VII. Germicidal Treatments of the Same.

I. Preparatory Treatment of Columbus Sewage.

The tanks in which these tests were made were seven in number, each 40 ft. long by 8 ft. wide by 8 ft. in average depth. Various linear velocities were used, ranging from 0.2 mm. per sec. to about 13 mm. per sec., for periods of flow roughly ranging from about 0.3 hr. to about 24 hr. The number of intermediate periods was quite large, plain sedimentation having been studied on the basis of 6 and 8 hours' flow; septic tanks on the basis of 4, 8, 16 and 24 hr.; and chemical precipitation for an 8-hr. period with reference to coagulation by sulphate of alumina and by copperas and lime. The preparatory treatments also included the straining of the raw sewage through coke in circular tanks. One of the strainers was about 130 sq. ft. in area, representing about 0.003 acre, and the other was about 43.5 sq. ft. in area, or about 0.001 acre. The depth of coke in these tanks was about 18 in., and the size of the particles about 0.25 in. in average diameter.

These different preparatory treatments were studied more thoroughly from the analytical standpoint at Columbus than at any other place in this country, excepting Worcester, and probably more thoroughly than in any one place in Europe. As already stated, it is one of the strongest portions of the Columbus work, and it puts the question of preparatory treatments of sewage on a basis quite comparable with that which the various investigations on the Ohio and Mississippi rivers accomplished with reference to the preparatory treatment of these muddy waters preliminary to filtration.

Prior to its application to the various preparatory devices

the sewage was screened through 0.5 and 0.375-in. mesh screens. About 300 lb. of wet screenings, largely kitchen refuse, were removed from the sewage for each million gallons of sewage pumped. This is equal to about 0.2 cu. yd. per million gal., agreeing in general with results elsewhere, as, for instance, at Paris, France, where the screenings amount to 0.25 cu. yd. per million gal., and at Manchester, England, where 0.28 cu. yd. of screenings per million gal. are arrested by triplicate screens.

For purposes of discussion it will be most convenient to tabulate average Columbus data with representative data elsewhere and then give a résumé of the writer's views on the subject of preparatory treatments.

TABLE No. 3.

COMPARISON OF THE REMOVAL OF SUSPENDED MATTERS BY DIFFERENT METHODS AT COLUMBUS AND ELSEWHERE.

Kind of Treatment.	Tank Capacity.		Percentage Removal.			
			Suspended Matter.		Total Organic Matter.	
	Hours Flow.	Linear Velocity. mm. per Second.	Total.	Volatile.	Nitro-genous.	Carbo-naceous.
Columbus.						
Grit chamber (small),	0.3	10.0	22	19	10	6
,, ,, (large),	1.5	2.2	34	29	19	15
Plain sedimentation,	6.0	0.56	63	54	30	26
,, ,,	8.0	0.42	66	58	31	31
Septic tanks,	8.0	0.42	61	51	29	24
,, ,,	16.0	0.21	66	60	35	32
,, ,,	24.0	0.14	67	62	36	36
Chem. precipitation,	8.0	0.42	81	88	53	53
Coke strainers,	...	...	80	77	53	33
Cologne.						
Plain sedimentation,	0.31	40.0	61	59	..	..
,, ,,	0.62	20.0	70	68	..	..
,, ,,	3.10	4.0	73	71	..	..
Hanover.						
Plain sedimentation,	1.75	8.0	..	60	..	..
,, ,,	2.30	6.0	..	59	..	..
,, ,,	3.50	4.0	..	55	..	..

Résumé of Preparatory Treatments. — 1. The use of screens to remove the coarser suspended matter is practiced in many places abroad more effectively than in America, and it appears to be of demonstrated practicability to operate self-cleansing screens having an opening of at least 0.125 in. or about 3 mm.

2. There are some sewages, particularly those containing trade wastes with fibrous material, such as at Reading, Pa., where it may be practicable to use much finer screens, perhaps

from 30 to 80 meshes per linear inch. At Reading, after the sewage had passed through a screen with about 0.25 in. openings, it was found possible to remove about 20 per cent. of the remaining suspended matter by a revolving screen of brass cloth having about 80 meshes per linear inch; at Leeds, England, Harrison states about 10 to 15 per cent. was removed by a 30-mesh screen; Monti found, at Berlin, rather higher results as a rule when working with a 0.5 mm. (0.02 in.) screen following a 15 mm. screen. The practicability of the fine-mesh screen depends partly upon the success of self-cleansing attachments and partly upon the life of the screen itself.

3. In the ordinary American sewage there are some 50 parts per million of what might be called "colloidal suspended matter," the size of particles of which is so small that they are held in suspension by vortexual movement and are not responsive to the law of subsidence.

4. Plain sedimentation is the cheapest way to remove from sewage those particles too fine to be removed by the finest practicable screens and too coarse to be called "colloidal matter."

5. Plain sedimentation in the case of the ordinary American sewage will remove from 60 to 65 per cent. of the suspended matter, and 30 to 35 per cent. of the total organic matter.

6. A velocity of flow of about 1 ft. per min., or, as the Germans say, "4 mm. per sec.," for a period of about 6 hr., is ordinarily the economical limit to which plain sedimentation may be carried. The basins should be designed so that this velocity will not be materially exceeded at times when some of the basins are out of service for cleaning and when a portion of the contents of the other basins is occupied with sludge.

7. Plain sedimentation basins require the sludge to be removed about once in three weeks, on an average, depending on the season of the year, in order to prevent putrefaction in the deposited sludge from becoming too active. At Columbus the volume of this wet sludge (87 per cent. water) was about 5.75 cu. yd. per million gal. This figure would have to be increased in the case of trade wastes, as at Worcester, but reduced for purely domestic sewage.

8. The septic treatment, as taken up at length in a subsequent portion of this paper, consists of plain sedimentation with provisions for the accumulating sludge to undergo putrefaction without removal more often than once or twice a year. At times of unusual bacterial activity considerable sludge appears in the septic effluent unless unusual care is taken in arranging stop-

planks and baffle-boards. The average removal of suspended matter in the septic tank is slightly below that of plain sedimentation tanks, other things being equal. The accumulating deposits of sludge, as compared with those in plain sedimentation basins, cause the septic tanks to be somewhat larger than the plain sedimentation basins.

9. The removal of bacteria in sedimentation or septic tanks seems to approximate that of the total suspended matter as shown from the data obtained from comparatively small sewage settling basins and from numerous water settling basins. Bacterial growths of certain species within a septic tank frequently obscure this general statement, which is intended to apply especially to those bacteria originally present in the sewage, and particularly the pathogenic bacteria.

10. With the aid of chemicals it is possible to coagulate some of the colloidal matters and after settling to obtain a much better clarified effluent than is possible with sedimentation basins or septic tanks. For coarse-grain filters the resulting effluent has been found satisfactory in many places abroad, but experiences at Columbus, and apparently also at Worcester, indicate that the resulting hydrate requires a comparatively long period in which to precipitate and become removed, otherwise the surface of the sand filters may become clogged by it. In this regard the treatment of the effluent from chemical precipitation tanks is not unlike the experiences at Cincinnati and New Orleans in the filtration upon sand beds of clay-bearing waters which had been previously coagulated and more or less perfectly settled.

11. It seems extremely doubtful for American conditions whether the additional cost of coagulating chemicals and additional settling basin facilities would be compensated by a corresponding increase in rates of filtration either through sand beds, contact beds or sprinkling filters.

12. Coke strainers were found at Columbus to behave in a manner similar to experimental tests made at Lawrence, Mass., and with the operations on a larger scale at Gardner, Mass. During warm weather they afford the most effective means of preliminary treatment and at a cost which is not excessive if the coke or other material used can be burned under boilers. Their cost with the necessary covers to insure satisfactory results in winter necessarily limits their usefulness to a marked degree, if it does not preclude it.

13. None of these preparatory treatments will, by itself, give a non-putrescible effluent.

II. Synopsis of Septic Treatment.

The writer endeavors to state briefly in the following pages his conception of the septic treatment with sufficient clearness, it is hoped, to facilitate discussion and criticism on the part of other workers in this field.

Septic Treatment Defined. — The septic treatment is taken to mean a preliminary treatment of the sewage by plain sedimentation in basins of such size that sedimentation is carried to an economical limit and at the same time provision is made for the accumulation of sludge which will disappear in part by bacterial decomposition and so that the residuum requires cleaning out only once or twice a year. Such a basin with ordinary American sewages will hold on an average about an 8-hr. flow; it is by no means comparable with septic tanks holding several times this period of flow and in which there is likelihood or certainty of the flowing liquid itself becoming septicized. It is, of course, not possible for the liquid in a septic tank to remain above the putrefying sludge without the liquid containing more or less gas and particles resulting from putrefaction, some of which are dissolved and some suspended, particularly ferrous sulphide, which gives the effluent a dark appearance. It is practicable, however, to design and operate a septic tank so that its effluent will not be materially impregnated with toxic compounds. This feature is of controlling importance.

The septic treatment is essentially one to promote the economical and inoffensive disposition of the sludge removed from the sewage by sedimentation, and it is not to any practical degree helpful for subsequent filtration except in so far as the original sewage is clarified by physical means.

Screening. — As pointed out in the excellent paper presented to this section last autumn by Messrs. Eddy and Fales, the sewage should be well screened before entering the septic tank. The special purpose of this is to guard against the entrance into the tank of those suspended matters which mass together and which are raised from the bottom of the tank by gas evolution to the surface, where they are apt to remain as scum, thus escaping full bacterial action and liquefaction.

Linear Velocities. — It is believed that linear velocities should not be reduced at the outset to less than about 1 ft. per min. It is quite likely that a higher initial velocity and a progressive reduction would prove helpful within certain limits. The purpose of this, as in the case of screening, would be to prevent a great accumulation of suspended matters at the inlet

where they are inadequately treated by bacterial decomposition. If such cannot be avoided, it will be helpful to convert the first portion of the so-called "septic tank" into a grit chamber, cleaning the same perhaps at fairly frequent intervals, and as in the case at Birmingham, England, pumping some or all this sludge forward into the septic tanks to undergo subsequent bacterial action.

From the writer's standpoint the keynote of success in the septic tank is to enable the sewage to be clarified within reasonable limits and for the resulting sludge to be converted by bacterial decomposition to an inert and inodorous mass.

Seeding. — It is by no means certain in the mind of the writer that proper provisions as to the two preceding elements necessarily constitute success for a septic tank. It may be even more important that certain kinds of bacteria shall be present in the sludge under such conditions that the sludge is converted to an inert and inodorous mass. Whether the sludge is reduced to this inert mass or whether it is largely in a putrefying condition is a most practical test of the accomplishments of a septic tank. This is a marked difference between the well-known septic tanks, for instance, at Plainfield, N. J., and at Birmingham, England. It may be that the right kinds of bacteria will establish themselves sooner or later in the sludge of almost any septic tank, but the writer is beginning to doubt it. On the other hand, it may be that much more than hitherto can be done by the manager of the plant to facilitate the right kind of bacterial action. It appears to the writer that the custom of Mr. Watson at Birmingham, England, is a judicious one — that of allowing well and suitably inoculated sludge to flow into the bottom of each clean compartment of the septic tank before starting to fill it with sewage. Satisfactory seeding is thus assured. Data upon this subject should be made more precise and, in accordance with the writer's recent recommendations for Plainfield, N. J., this should be looked into most carefully, from the standpoint of both the bacteriologist and of the engineer. For the bacteriologist it is probably the biggest single problem on his hands in the field of sewage purification.

If it ordinarily takes from one to three weeks for septic action to establish itself, it will be readily seen that "seeding" with the proper kinds of bacteria should have an advantage from the standpoint of time as well as of ultimate decomposition.

Effect of Seasons. — Like all bacterial processes, the intensity of septic action is responsive to temperature conditions in a large

measure. This is well indicated by Table No. 4, showing the percentage by months which the gas produced from septic tanks at Worcester, Mass., is of the mean volume of gas.

TABLE No. 4.

PERCENTAGE WHICH THE VOLUME OF GAS PRODUCED EACH MONTH IN SEPTIC TANKS IS OF THE ANNUAL MEAN.

January	30	July	140
February	62	August	167
March	48	September	170
April	51	October	116
May	100	November	115
June	148	December	65

In all septic tanks there are numerous irregular fluctuations, but it is usual to see a ratio between maximum and minimum of about 5 or 6 to 1, as was the case at both Worcester and Columbus.

The questions of bacterial antagonism and other features than temperature are, of course, to be considered. But it is especially to be pointed out as explaining the wide discrepancies which have appeared in reports from various places upon the amount of sludge decomposed, and it makes a vast difference whether the data given refer to the cold winter months when the bacterial processes are working at a rate far lower than the average or whether they refer to the spring and early summer months. During the latter it is not unlikely that there are periods when the amount of sludge that is septicized will greatly exceed the total amount of sludge entering the tank for a time. These are the times when the winter accumulations largely disappear. Data as to the effectiveness of septic treatment in disposing of sludge should refer to the work of practically an entire year in order that the information may be utilized by others in a safe way.

Varying Treatment at Different Seasons — Flexibility of Design. — The writer is convinced that a septic tank should be designed with various compartments so that portions may be used from time to time and other portions temporarily thrown out of use if current analytical data should indicate that to be desirable. When the sludge in the tank is undergoing intense bacterial action, which usually occurs two or three times each year, arrangements should be made for throwing that tank out of service until the action practically ceases. Even with a set of tanks side by side these periods are not usually simultaneous.

Large amounts of decomposed sludge may be belched forth in the effluent with more or less unsatisfactory results in several ways, if care is not taken. After such a period of intense bacterial activity it would appear to be a logical time to clean the residual sludge from the tanks, but taking care to leave enough to "seed" the incoming sludge with the right kinds of bacteria.

The cost of division walls to provide the various compartments of a septic tank, by-passes and independent inlets and outlets is a wise investment.

This is especially true of works for small towns where the number of house connections made to a new sewer system is very small during the early life of the works. Without this flexible aspect of the septic tank it seems almost certain that trouble would result at the outset with a sewage which is very old even before it reaches the septic tanks.

Briefly stated, the septic tank ordinarily works very well; there are some exceptions, and it is now a question of bringing under control these exceptional conditions. This requires a better-designed tank than is now built, as a rule, and it calls for better management. If this process is fully satisfactory 350 days in a year, it is not to be forgotten as a last resort that there are many things, like the use of strong chemicals, by-passing the sewage around the septic tanks, etc., which can be done for 15 days and still have the net annual result very satisfactory.

Reduction of Sulphates. — At Columbus, owing to the exceedingly hard water with which the city is supplied, the sewage is highly charged with sulphates of lime and magnesia. In some instances elsewhere it appears that the sulphates are reduced by bacterial action to sulphides, in some instances sulphureted hydrogen being given off. This matter was studied carefully at Columbus and there was no indication of bacterial decomposition of sulphates. This is one of several observations upon which the writer predicates his thought that the "seeding" of septic tanks and the control of bacterial decomposition of sludge with suitable species is a matter upon which we have much to learn.

Over-Septicization. — The observations of the writer during recent visits to Europe lead to the conclusion that for the diluted sewages in America the septic treatment can be applied much more satisfactorily than for the strong sewages abroad. The sewages there are three to four times as concentrated as those in this country, and consequently to provide equivalent capacity for

the accumulation of sludge a tankage three to four times as great is required as with our weaker American sewages.

It is the belief of the writer that this set of conditions is far more favorable for American practice than is now realized. It means that the benefits of septic treatment may be secured with a far less likelihood of those complications which result from over-septicization, which might be defined as bacterial decomposition carried to a point where the sewage itself is highly charged with toxic compound resulting from such bacterial decomposition.

Production of Odors. — At Columbus no trouble was encountered with odors from septic tanks. It is not intended that this statement shall convey the idea that absolutely no odors of a sewage nature were to be found. That condition of affairs does not exist at any sewage purification plant, even an experimental one, if it is regularly operated for ten or twelve months. It means that no objectionable odors were noticeable, and this is the view point which should be held when this subject is considered in relation to large projects.

So far as the writer's personal observations are concerned, he has never noted any seriously objectionable odors at any of the septic tanks in practical operation in this country. He is aware, however, that such disagreeable odors were recorded at Worcester, Mass., and Pawtucket, R. I. Such experiences, however, have not been duplicated at Plainfield, N. J.; Saratoga, N. Y.; Mansfield, Ohio, and a number of other places where septic tanks of some size have been in service for a number of years. So far as he knows, no complaints have arisen in this country leading to actions at law so far as odors from septic tanks are concerned.

In regard to odors from septic tanks in England, there is a wide discrepancy in opinions recently stated in this country. Undoubtedly there are some septic tanks in England which, on account of their excessive size and other abnormal factors, have produced odors which may be properly called serious. On the other hand, the percentage of such instances is really very small according to the personal observations of the writer, who has three times visited England since the septic tank came into wide use. Two of these visits were during the summer months and one of them during the winter, shortly before the visits by a representative studying the problem for Paterson, N. J. The quotations in the Paterson report as to trouble from odors in and around septic tanks in England are, in the opinion of the writer,

almost certain to lead the inexperienced reader to incorrect conclusions on that subject.

To say that odors from septic tanks or from the aëration of septic effluents are objectionable for long distances, say perhaps, for 0.5 to 1 mile, is an over-statement which is not borne out by the fact so far as the writer has been able to ascertain by personal inspection and personal inquiry. In fact, the most striking feature with the connection of odors since the introduction of the so-called "biological method" has been their diminution. The abandonment of sewage farms in England has reduced the number of suits in court for alleged damages from this cause.

It is not the desire of the writer to claim that the odor factor does not exist in connection with septic tanks, but searching efforts made in England last September, at the end of an extremely hot period, convinced him that the statements made at the International Engineering Congress in 1904 at St. Louis, by Mr. H. Ross Hooper, M. Inst. C. E., engineer inspector of the Local Government Board of England, were practically correct.

> "*Nuisances arising from Sewage Disposal Works.* — This may be said to be practically *nil*, unless due to the lack of intelligence on the part of employees. It may be said that the fact that many hospitals, asylums, recreation grounds, etc., often adjoin the works without any bad effect is sufficient to prove that they are not necessarily dangerous neighbors."

In connection with careful inquiries made into this and allied subjects for the Baltimore Sewerage Commission last year, it was concluded that a project involving septic tanks to dispose of the sewage of at least 600 000 people ought to be designed, built and operated so as to cause no objectionable odors at a distance of not more than 0.25 mile from the septic tanks. This conclusion is a fair statement of the case in the opinion of the writer.

In connection with the subject of odors it is to be clearly understood that reference is not made to septic sludge, but to odors from the tanks themselves and from the septic effluent, either with or without aëration. Undoubtedly there is much to be learned about the bacteriology of this subject and the writer looks forward in hopes of seeing the day come when these matters can be handled far more skillfully than at present. If no serious odor at all is found at the largest installation in the world, at Birmingham, England (and it is claimed by some that this is due

partly to waste iron liquors and partly to the right kind of putrefactive bacteria), who can say that later on these conditions cannot be artificially provided elsewhere without difficulty?

Covered Septic Tanks. — In a majority of instances the writer has advised the use of uncovered septic tanks, although for climatic reasons he has favored the use of covers for some cases.

With properly designed septic tanks, so that the operation may be adjusted within a fairly wide range of conditions, the writer is still of the opinion that covers, so far as odors are concerned, are not necessary with the weak American sewages.

With strong English sewage, particularly those from which sulphate reductions occur, there is a good deal to be said in favor of covers, as is well summarized by Mr. George R. Strachan, M. Inst. C. E., the distinguished sanitary engineer of London, in his report on the Toronto problem last summer as follows:

"There can be little doubt that the processes of septicizing go on as efficiently in an uncovered tank as in one that is covered when once the scum has formed and remains intact. The Toronto tanks were to be covered for climatic reasons, and, therefore, the issue does not, strictly speaking, arise in this case, but it may be well to state that the odors from open septic tanks have been abominable in several cases of nuisance I have investigated. There are open tanks without offense, such as those at Birmingham, but the sewage there is much mixed with trade wastes, which seem to give it an impunity in this respect. In every case of open tanks I know of where the sewage is domestic, offense is present and often in a pronounced form. The trouble arises in three ways. There is first and continuously the ebullition of new septic sludge through vents in the scum, which gives off putrid odors when drying in the air and sun. There is second, and frequently, the wetting of the scum by rain and the subsequent bad odors during evaporation and absorption. Then a third and less frequent offense is caused by the wind compressing the scum into a more solid mass and leaving a part of the septicized sewage exposed."

For American conditions where it is not too cold the writer would prefer to guard against odors with an open septic tank of a flexible design as heretofore indicated rather than with a covered tank built like many of those in use in England. In fact, it is only fair to state that many septic tanks abroad are merely adaptations of former chemical precipitation tanks.

Disposition of Septic Sludge. — This is the real problem

with the septic process under American conditions, according to the writer's experiences. At Birmingham, England, where this process is best carried on, the sludge is an inert humous mass, practically inodorous. It is usually applied to land in depths of about 8 to 10 in. and will usually evaporate to about one third of that thickness within a few months. This sludge will not support vegetation. The idea prevails among many that sludge from the Birmingham septic tanks requires to be plowed in. This is not so. It is a mere coincidence that the plowing occurs. With a large area of land they naturally have no desire to get any portion of it treated with so thick a layer of sludge that it is no longer responsive to agricultural pursuits. Naturally they apply this sludge in very thin layers and plow it in with a steam plow in order to mix the same very thoroughly.

The sludge from grit chambers at Birmingham is by no means free from odors, due to the fact that it contains much organic matter which has not passed through the putrefying stage. It is very interesting to note that this fairly fresh sludge from the grit chambers is frequently covered with a layer of septic sludge in order to guard against odors when applying the former material near roads, etc.

In most cases in America the trouble with septic sludge has been that it resembles the grit chamber sludge of Birmingham and not the septic sludge at that place. The real problem ahead of us is how to correct this, because, if this is done, it insures an extremely economical means of disposing of one of the most awkward elements of sewage purification by applying the residuum to land and allowing it to air-dry.

As to the amount of sludge from septic tanks, it was estimated at Columbus (combined sewers) to be about 2.68 cu. yd. per million gallons of sewage treated. Two cubic yards were used in the Baltimore estimates with a separate system of sewers. This corresponds roughly to a reduction in the weight of total deposited matters of about 50 per cent. on an average. In the winter the reduction is far less than this, but in the spring and summer it is much more.

At Columbus provision is made for disposing of septic sludge either upon land or upon the Scioto River at times of flood flows. The latter procedure is, of course, quite unusual and one which could not be carried out at many places elsewhere owing to the lack of similar conditions. It may be stated here that this disposition is by no means so incompatible with sound hygiene as would appear at first sight. If our present informa-

tion as to the longevity of disease germs in sewage counts for much it shows that there is not great danger in this sludge, — much less, in fact, than in fresh sewage which enters the river at Columbus and elsewhere at each storm when the combined sewers overflow.

While the disposal of sludge at Birmingham without any attending bad odors is a chief step in advance accomplished by Mr. Watson, it is very gratifying to note that he does this at a cost of only five cents per cu. yd., or 10 to 15 cents per million gallons of ordinary American sewage.

Separate Tanks for Septicization of Sludge. — Several schemes have been proposed relative to the withdrawal of sludge from settling tanks in order that septicization of the sludge may occur in separate tanks from those through which the main body of the sewage passes. It is claimed for this procedure that it aids in reducing odors in the settled liquor as applied to filters, especially those of the sprinkling type.

Obviously it would add much to the cost of operating sewage works under ordinary conditions as to arrangements. The cost of construction would also be materially increased if the secondary tanks are large enough to store the accumulation of sludge during the cold season.

It seems to the writer very doubtful whether any advantage corresponding to the increased cost would result from this scheme either as to odors at the tanks themselves or of the settled liquid as applied to the filters in the event that the effluents from the settling tanks and the separate septic tanks are united. The reason is that if a given amount of organic matter is subjected to bacterial decomposition and the same bacterial results are accomplished, it seems an obvious proposition that the by-products would be the same as they are proportional to the amount of bacterial work accomplished.

There might be some advantage if the effluent of these septic tanks were to be treated in, say, contact filters rather than on sprinkling filters. This is the only way in which this scheme appears meritorious to the writer.

It may be that those favoring this arrangement intend to dispose of the sludge without having it well septicized. So far as application to land is concerned, the writer is opposed to decomposing as compared with decomposed sludge.

Hygienic Efficiency. — It is the writer's view, even in places where bacterial growths occur in septic tanks so that the numbers in the effluent exceed those in the influent, that the hygienic

efficiency of the septic tank in round numbers approximates the removal of the total suspended matter. This, of course, refers to the bacteria present in the liquid entering the tanks and especially those species of a pathogenic nature which do not grow within the tanks.

There is a good deal to support the thought that the removal of bacteria in septic tanks from a hygienic standpoint is considerably in excess of the removal of total suspended matters. This brings up the question of bacterial antagonism, which requires considerable study to establish its practical significance with regard to septic tanks.

Bacteriologists have quite a task before them to put matters upon this score in definite terms, and it is none the less important because so many of the data are obscured by growths, the significance of which is not fully understood.

III. Intermittent Sand Filtration.

At the Columbus Testing Station more of the processes included intermittent sand filters as a portion of the method of purification than any other style of filter. The results obtained were in general harmony with the long and well-known studies and experiences in Massachusetts. There was nothing very new or startling learned from the sand filter tests, although the advantages of giving the sewage a preparatory treatment were set forth in perhaps a more comprehensive and comparable manner than elsewhere.

It was found that plain sedimentation on the whole was rather the best preparatory treatment, although coke strainers during the warmer season of the year were found to be even more satisfactory. Septic treatment was of no advantage as compared with sedimentation, and there were times when there was something of a disadvantage, owing to the sludge belching forth with the effluent. In practice this could be largely reduced in a plant well built and well managed.

As to chemical precipitation, references have already been made to the experiences encountered similar to those of Mr. Eddy at Worcester, namely, the appearance of the coagulated masses upon the surface of the beds. This led to undue clogging and could be avoided only by the use of basins of larger capacity. This would increase the cost to a point where this method would hardly be of much use.

There has been recently a good deal of comparative discussion of sand filters for sewage purification, some of it warmly

advocating the process and some of it otherwise. The Columbus work from a broad practical standpoint is chiefly of interest because it has shown that at a locality where sand could be laid down in place for about $1.25 per cu. yd., yet sand filters of artificial construction cannot be economically built in comparison with the more modern contact filters and sprinkling filters. The Columbus sand filters were estimated to cost $8 940 per acre complete, but exclusive of land and engineering.

The same conclusion was reached by the advisory engineers at Baltimore in their report last spring. While there is much good sand within a moderate distance of the city, so much of it is in very thin strata, and so much is mixed with clay, it was found cheaper to build artificial beds, the cost of which was estimated at $6 350 per acre, including engineering, but excluding land. This latter project was found to be more expensive than sprinkling filters followed by sand filters for a finishing treatment.

Still another illustration of the cost of sand filters is afforded by the recent report of Messrs. Hering and Fuller to the International Waterways Commission on the cost of purifying the sewage of an assumed population of 1 200 000 people on the Calumet area south of the City of Chicago. These figures are summarized as follows:

TABLE No. 5.

	Kind of Filter.		
	Sand.	Contact.	Sprinkling.
Construction cost, with appurtenances	$11 063 000	$11 787 500	$9 257 500
Annual operating expenses capitalized at 5 per cent	17 320 000	11 020 000	8 380 000
Total	$28 383 000	$22 807 500	$17 637 500

In each of the above projects are included intercepting sewers, pumping stations and force mains connecting with the septic tanks and filters.

Notwithstanding the above, the writer is clearly of the opinion that the intermittent sand filter, which has served and is serving such a useful purpose in Massachusetts, is by no means an institution of the past. Its efficiency is high, and where suitable areas of porous sand are near at hand it is frequently the cheapest method that can be availed of, especially for towns and cities not exceeding 30 000 or 40 000 population. For large communities the intermittent sand filter does not seem to

be so applicable, owing to lower operating expenses for large filters of other types.

With sewage which has been screened and settled for perhaps 0.5 hr. it was found that a rate of 100 000 gal. per acre daily was about the full normal load. The test filters at Columbus contained 3 ft. of Lake Erie sand of an effective size of about 0.25 mm.

The above load corresponds to the sewage of about 800 persons per acre. This is closely in accord with Lawrence data, which the writer computes from the amount of applied nitrogen as given by Mr. H. W. Clark in the 1904 Report of the Massachusetts State Board of Health, pp. 212–15, and on the assumption that each person at Lawrence contributes 13 g. of nitrogen daily. These Lawrence data refer to the outside filters and not to the small indoor tanks.

TABLE No. 6.

COMPUTATIONS OF LAWRENCE SAND FILTER LOADS, 1904.

Number of Filter.	Kind of Material.	Effective Size in mm.	Years in Service.	Av. Gals. per Acre Daily.	Av. No. Persons per Acre.
1	Coarse sand	0.48	17	61 110	730
2	Fine sand	0.08	17	31 700	380
4	Very fine sand	0.04	17	20 200	260
6	Sand and gravel	0.35	17	49 200	630
9	Medium sand	0.17	14	60 300	785

Such rates as indicated by the above are not wholly in accord with some of the data of sand filter plants in actual practice in Massachusetts. Where the rates in practice are recorded as much higher it is believed that they represent only a short period of loading and that filter extensions must soon follow. Other cases in Massachusetts are to be found where the rates in practice are lower than necessary. In this connection it is of interest to compare the data from the 1903 Report of the Massachusetts State Board of Health.

TABLE No. 7.

MASSACHUSETTS SAND FILTER LOADS, 1903.

Place.	*Population.	Place.	* Population.
Andover	950	Natick	360
Brockton	1 160	Pittsfield	605
Clinton	425	Southbridge	305
Concord	365	Spencer	320
Framingham	375	Stockbridge	220
Gardner (old)	1 310	Westboro	750
Gardner (new)	2 000	Worcester	1 390
Marlboro	840		

* Population connected with sewers for each acre of filter.

At Lawrence the clarification of the sewage led to higher rates, as indicated in Table No. 8, computed by the writer for his paper on "Sewage Disposal in America," for the International Engineering Congress.

TABLE No. 8.

Kind of Preparatory Treatment.	Years Tested.	Rates of Filtration through Medium Sand. Gal. per Acre Daily.
None	1891–1902	58 688
Filtered through gravel	1892–1897	503 030
Sedimentation	1893–1897	177 049
Coke strainer	1894–1899	236 587
Chemical precipitation	1893–1897	188 065
Septic treatment	1898–1902	208 024
,, ,,	1898–1902	184 235
,, ,, *	1899–1902	212 253

* Aërated.

At Columbus it was found that sedimentation and septic treatment allowed rates to be used satisfactorily up to 250 000 gal. per acre daily and even a little higher. As the filters grow older it is quite debatable whether the cost of operation during the winter would not make lower rates more advantageous in practice.

The question of balancing rates of filtration and operating expenses to give the most economical results for large plants in practice is one upon which present evidence is not as definite as desired.

Another question is whether sedimentation enables the rate to be tripled, as compared with the requirements for unsettled sewage, and thus keep the applied suspended matter the same; or whether it permits the rate to be increased 50 per cent., thus keeping the applied organic matter a constant.

IV. Contact Filters.

The contact filters which were tested at Columbus were 5 ft. in depth. The size of the material ranged from 0.25 to 2 in. They were found to be capable of giving a non-putrescible effluent when the applied sewage had been clarified by sedimentation or septic treatment at a rate of from 600 000 to 700-000 gal. per acre daily on an average.

Comparing these conclusions with other experimental data in this country as well as other experiences in practice in this country and abroad, there seems to be a substantial harmony. For a contact filter of the ordinary depth of about 4 ft.,

it seems hardly practicable to figure on a net average rate of more than 500 000 gal. per acre daily. For short periods this rate, of course, can be much exceeded.

The most striking feature of the American experiences with contact filters as compared with those abroad is that the rate of purification seems to be substantially the same regardless of the marked difference in the strength of the sewage. This constitutes one of the essential differences between contact filters and sprinkling filters. It also furnishes an excellent basis for testing the validity of numerous theories as to the operation and accomplishments of contact filters.

At Columbus it was found that the contact beds arranged for double treatment gave more satisfactory results per unit area of total filtering surface than where there was only single contact. The difference was not striking, however.

Some attention was given at Columbus to the question of operating contact filters from below with a special view to operating sprinkling filters temporarily in this manner during periods of very cold weather. The procedure was found to be practicable, although, of course, in the case of double contact it is far better than with single contact. In the latter instance the sewage which last enters the filter leaves first and hence is not wholly purified. This feature is overcome with the double contact.

The filling of contact filters from below is, of course, not by any means a new story. It was studied many years ago at Hamburg, Germany, by Professor Dunbar. In the opinion of the writer it has more practicable merit than it has been credited with up to this time. It is being regularly used at Langensalze, Germany, and at Hampton, England, with apparently satisfactory results.

It is the most successful way there is of keeping a sewage obscured from view until it has reached the non-putrescible state. It also gives an exceedingly high quality of effluent when the double contact filters are followed by a third filter or strainer of sand or some other material.

The writer recently recommended this treatment for the sewage of the Soldier's Home, Togus, Me., where a high grade of effluent was sought, not only during summer conditions, but also during the winter, when it would have to contend with both heavy snows and low temperature, and also with comparatively small stream flows in the brook which receives the effluent.

The contact filters were shown 5 ft. in depth and provided with a false floor, substantially as in the case of sprinkling

filters. It is not intended that the surface of either the primary or secondary contact filter would ever be covered with sewage. In fact, during the winter it will be the purpose to fill the contact filters from below only to within about 1 ft. of the surface. This effluent, which will be non-putrescible and distinctly turbid, will be settled for a very short time and then passed through a sand filter, which should uniformly produce an effluent of brilliant appearance and high-grade purity.

The contact filter has served a useful purpose where sand filters could not be advantageously installed and will, no doubt, continue to do so in the future, especially in those instances where it can be used without pumping and where pumping would be required for sprinkling filters.

V. Sprinkling Filter.

The most important single point learned at Columbus was probably that of the practical accomplishments of sprinkling filters under such a northern climate during the winter season. With fixed sprinkler jets it was found at a temperature of 10 degrees below zero that there were no complications as to clogging with suitably designed orifices and that a considerable number of days might elapse under such conditions without the amount of frozen sewage accumulating to a degree interfering seriously with the results of filtration. Compared with previous views held in this country, this was a great step in advance, as it meant that the sprinkling filter, with its ability to produce a non-putrescible effluent at rates of filtration three to four times as great as in the case of contact filters, was a practicable proposition.

Method of Dosing. — It is unnecessary to enter into this subject at length, as its features for the works adopted at Columbus have been described in the *Engineering Record* of December 30, 1905, and the details of the sprinkling nozzle have been set forth by the designer, Mr. John H. Gregory, in the Proceedings American Society Civil Engineers, September, 1906. The use of this large orifice, above which is placed an inverted cone, is a marked improvement as compared with the small orifices more generally used in Europe and which involve considerable expense for cleaning. After having visited practically all of the experimental stations in this country and Europe and representative plants where each method of distribution is used in practice, the writer is clearly of the opinion that the Columbus method of application of the sewage to sprinkling filters is by far the best and cheapest.

The use of the large orifice for the sprinkling nozzle at Columbus arose from the plan of using a rate of 4 000 000 gal. per acre daily for the sprinkling filters during the time that the latter were actually in service. It is perfectly feasible to use such a large orifice or even a still larger one with the aid of a dosing tank or reservoir in which to store up the influent for a number of minutes and from which it is then discharged to the sprinkling filter through such orifices. In the sprinkling filter plant now under erection at Reading, Pa., the writer has advised the use of a dosing tank which would require about a ten-minute interval for filling and emptying. Accordingly, during each ten-minute interval the liquid would be applied through the nozzle under a range of head from the maximum to the minimum. This would cause, during each ten-minute interval, about 80 per cent. of the area of sprinkling filter surface to be covered with spray in a substantially uniform manner. Practically speaking, this is very nearly perfect, when consideration is given to the marked influence exerted by a slight wind on this fine spray.

Filtering Material. — The tests at Columbus were conducted with material of a size ranging from about 0.5 to 2 in. The writer's observations at various works in Europe have led him to conclude that this is too fine in order to maintain a vertical circulation of air at all times. The actual mean diameter of the particles ranging from 1 to 2.5 or 1 to 3 in. is considered preferable. The finer material gives a somewhat better effluent than the coarser beds, other things being equal, but the difficulty in getting ample air into the pores of the finer material and the cost of cleaning the same in the event of clogging, causes the writer to lean much more strongly to coarse material than he did during the Columbus tests.

As to the depth of material, the 5-ft. beds at Columbus are undoubtedly a minimum. They will allow a non-putrescible effluent to be obtained, but for reasons of economy and efficiency it is desirable to make the filters somewhat thicker. Generally speaking, the writer favors a depth of 6 to 7 ft. At Baltimore a depth of 9 ft. was recommended under conditions where it was urgent to secure the highest form of bacterial removal.

In the recent report made to the International Waterways Commission for the disposal of sewage of the Calumet area near Chicago, a depth of 7 ft. was advised for the sprinkling filter project. The reason of this was to a considerable degree due to

the desirability of making the area liberal for meeting the extreme weather conditions in winter. At such critical times it is clear that the best investment of a certain sum of money does not lie in very deep beds. Just exactly how all these questions of depth of bed, size of material, etc., will be ultimately adjusted can only be told after more experience on a large practical scale has been obtained.

Retaining Walls. — In the paper which the writer presented to the International Engineering Congress in 1904, reviewing the status of sewage disposal in America, it was suggested that one of the advantages of sprinkling filters was that they needed no retaining walls. As soon as the writer had occasion to figure upon the details of various projects it was quickly ascertained that it is cheaper to build retaining walls than it is to increase the floor and false bottom and filtering material sufficiently to create an angle of repose for the filtering material. In other words, the "heap-of-stone" theory cannot be taken too literally, as it is really cheapest to build a concrete basin and fill it with material.

One of the principal reasons why the writer mentions this point is the possibility of using sprinkling filters temporarily as contact filters. Mr. John H. Gregory, in designing the main works at Columbus, has arranged that this might be done whenever desired during extreme winter weather and when there might be danger of getting too much frozen sewage on the surface of the filters.

There is another set of conditions where sprinkling filters might to advantage be operated temporarily as contact filters, namely, in adapting them to a community which is just being provided with sewers and where the number of sewer connections is at first very small. It is quite feasible that the sewage might become over-septicized before reaching the sewage works and thus temporarily give unusually bad odors. The idea of operating sprinkling filters as contact filters under such circumstances as these was included in the project recently recommended by the writer for the borough of North Plainfield, N. J.

Odors. — The distribution of sewage in the form of spray naturally intensifies any tendency towards bad odors. It is the writer's practice and endeavor to keep sprinkling filters at least 0.25 mile away from roads and buildings. Under this condition he has no fear that a well-built and well-managed plant will give trouble from odor, notwithstanding the occasional opinion expressed to the contrary.

Capacity. — As a result of the Columbus tests it was concluded that with a sewage corresponding to about 120 gal. per capita daily, and including street wash, a rate of filtration of 2 000 000 gal. per acre daily on an average was feasible. The main works at Columbus are designed substantially on this basis, although a portion of the present city will be on the separate system. It is stated in round numbers that a 10-acre plant will serve a population of 200 000 people. This makes a load of 20 000 people per acre on a filter bed 5 ft. deep, or 4 000 people per acre-ft.

In England, 1 000 000 imperial gal. or 1 200 000 U. S. gal. per acre is the ordinary load which corresponds to about 30 000 people for a bed which is usually 6 to 8 ft. thick. There are instances, such as at Accrington, where an area of less than one acre of beds averaging about 8.5 ft. in thickness are taking care of the sewage of about 50 000 people.

One of the most characteristic features of the sprinkling filter as distinguished from the contact filter is its ability to operate at various rates with sewage of different strengths but which bring about the same load as to organic matter, other things being equal. In other words, here is a style of filter which will take care of the sewage of as many people per acre with the dilute American sewage as it will with the concentrated European sewage. This is an advantage, the significance of which is not yet fully appreciated. It is hardly feasible yet to name the standard load per acre-ft., as that depends largely upon questions of street wash, trade waste and climatic conditions, as well as upon the question of whether it is desired to secure a high removal of bacteria or simply secure a non-putrescible effluent. During fairly warm weather there seems to be no trouble whatever in operating sprinkling filters at rates of 6 000 people per acre-ft., but during the winter these rates must undoubtedly be lowered materially for northern climates. In the recent report to the International Waterways Commission, Messrs. Hering and Fuller applied a factor of safety resulting in a layout with one acre of sprinkling filter surface 7 ft. deep for each 15 000 population. If such a plant were operated it is probable that half of the sprinkling filter would do the work during nine or ten months of the year.

Cleaning. — A notable characteristic of the sprinkling filter, as is well-known, is its self-cleansing properties. This necessitates a false bottom with ample slopes both to the floor and to the main collectors. With reasonable care it is believed

that a sprinkling filter will operate under good management for ten or fifteen years without cleaning. Such low operating expenses when capitalized and added to the construction cost form one of the chief reasons why these recent sprinkling filter projects have made such a favorable showing in comparison with both contact filters and sand filters.

Already in several places in Europe filters have been operated regularly for over seven years without cleaning. It does not follow, however, that they do not require attention to prevent clogging. In the opinion of the writer the sprinkling filter is a much more efficient institution when operated intermittently than when operated continuously. Just what the best degree of intermittency may be can hardly be told now as it depends a great deal on the size and character of the filtering material. At Columbus, Mr. Geo. A. Johnson thought that it was highly desirable to provide long periods of rest. They were undoubtedly helpful in causing the unloading of stored material, but whether they were necessary or not under regular conditions of practice cannot now be told.

Bacterial Removal. — The removal of bacteria by the sprinkling filters at Columbus was about 70 per cent. of those in the applied liquid and it is estimated to be about 90 per cent. when compared with the bacteria in the original sewage. These results obtained with 5-ft. beds would be much higher with deeper beds. The Lawrence data indicate that there would be a total removal of from 95 to 97 per cent. with 10 ft. filters. Although the latter filters would also give higher nitrification, it is debatable whether this is the best way to secure such removal of bacteria.

VI. Sedimentation and Filtration of the Effluents of Coarse Grain Filters.

So far as the writer knows, there is no instance in this country where the effluent of contact filters has been settled. When the filters are filled from above the effluent is usually sufficiently well clarified to make that treatment unnecessary.

In the case of contact filters filled from below it is believed that it might be advantageous under some circumstances to adopt a clarification of the effluent by sedimentation substantially as is required with sprinkling filters. The sedimentation of the effluent from double contact filters filled from below, and its subsequent filtration through sand, is a feature of a disposal plant recently designed by the writer for Madison, N. J.

Successful sprinkling filters produce an effluent in which the suspended matter on an average is fully as great as in the influent. The amount of suspended matter varies widely, due to the irregular elimination by the filter of the matters removed from the sewage in the form of films around the filtering material. Some of the fine colloidal particles pass directly through the filter and others are retained upon the sticky surfaces of the material. Particularly after resting and drying, these films become detached, and as has already been explained in connection with the cleaning of sprinkling filters, one of the chief characteristics of this type of filter is its ability to convert fine suspended matter in the influent to coarse suspended matter in the effluent.

Where non-putrescible results alone are desired it is sufficient to settle the sprinkling filter effluent for from one to two hr. in order to deposit those particles of a fairly coarse nature. Columbus data indicate that on an average such deposit amounts, under local conditions, to about 1 cu. yd. per million gallons. The other suspended particles in the sprinkling filter effluent are so fine that they cannot be removed by subsidence.

Test of Putrescibility. — In passing it may be stated with reference to putrescibility that it is the opinion of the writer that field tests made at the works at frequent intervals to show whether or not the effluent is putrescible are generally more helpful than complete analyses of the effluent made at intervals of once a month or so. As a guide to the man in immediate charge of such a plant there is no comparison between the aid derived from the two styles of testing.

After examining carefully the various methods used in the laboratories in this country and in Europe, it is the writer's opinion that the present form of the putrescibility test applied under the direction of Dr. Scudder in the Mersey and Irwell valleys is the simplest and most practicable. It consists in mixing equal volumes of the effluent and of well-shaken tap water and allowing the same to be incubated at a fairly high temperature for 24 hr. A qualitative test is then made for dissolved oxygen. If oxygen is still present the result is considered satisfactory.

Dr. Scudder tells the writer that this has done a great deal of good in the hands of local managers of sewage works, as it not only develops self-confidence, but stimulates greatly the interest of the local management in seeing that the results meet a practical test which they themselves can both understand and apply. The beneficial aspect of this state of affairs is great

in comparison with conditions surrounding the results of analyses made at a central laboratory at more or less irregular intervals and the results of which when received some days later are viewed in many cases by the local management with feelings of uncertainty.

Improved Bacterial Results by Filtration. — At Columbus a number of tests were made to show the improvement in sprinkling filter effluent resulting from filtration through sand following sedimentation in intermediate basins. The data can be regarded only as suggestive for the most part, as the facilities were not well adapted to testing this feature very satisfactorily. The extended data obtained by Mr. H. W. Clark at Lawrence on this subject afford a much better index.

A review of all the data bearing upon this subject in connection with the Baltimore problem last spring led to the conclusion that sand filters 3 ft. deep could operate at about an average rate of 750 000 gal. per acre daily. Such an effluent would contain ordinarily only about 1 per cent. of the bacteria in the applied sewage and would also be practically free from turbidity.

In connection with the Baltimore proposition the writer gave considerable attention to the use of mechanical filters for the final purification and clarification of the sprinkling filter effluent. With mechanical filters built in a plain, substantial way about like the best mill filters, it was found that the total cost, both operating and capital charges, would be the same for mechanical filters as was estimated for sand filters, if the sprinkling filter effluent could be satisfactorily coagulated with sulphate of alumina when applied at an average rate of 2.125 gr. per gal.

Various tests on a small scale were made by a number of workers to ascertain the amount of required coagulant and the results showed such a wide range that the project was decided by the advisory engineers to be too indefinite for recommendation. The extreme range was from 1.25 gr. of sulphate of alumina, required for several effluents tested by Mr. A. E. Kimberly in Ohio, to about 3.5 gr., required for settled sprinkling filter effluent by Mr. H. W. Clark at Lawrence.

How far the use of copperas and lime might bear upon this question of cost of coagulating sprinkling filter effluents for use in mechanical filters is not yet clearly understood. Some preliminary tests in this direction were made, but as a rule it was found difficult to get the iron separated out as a hydrate.

VII. Germicidal Treatment of the Effluent of Coarse Grain Filters.

The supplementary treatment proposed for Baltimore by means of sand filtration is estimated to cost $3.91 per million gallons for operating and capital charges. On the evidence available at that time it was considered that there was no reliable means of treating the effluent of sprinkling filters with a germicidal chemical to give results equal in efficiency to the sand filtration treatment and at as low a cost.

Within the past few months there have been a number of important developments in several branches of the field of germicidal treatment. The writer will refer briefly to a few points to facilitate discussion.

Ozone Treatment. — So far as the writer knows, the use of ozone has never been seriously considered in connection with sewage effluents. In fact, for water purification purposes there have been two serious drawbacks to its tentative use in Europe, one being the irregularity of its production by the best devices, and the other the cost of its production. Recently the United Water Improvement Company at Philadelphia, Pa., has claimed that recent discoveries by members of its staff enable from 65 to 80 g. of ozone to be produced per kw-hr. This is four to five times as much ozone as could be produced per kw-hr. as previously figured. If this is true it has an important practical significance.

Test devices are now about completed by which the use of ozone for purposes of sterilizing and bleaching the Croton water may be thoroughly studied at the testing station of the Water Department of New York City at Jerome Park Reservoir. The essential data as to the production of ozone will no doubt be fully developed here in due time.

Copper Sulphate. — This is still being studied by the Bureau of Plant Industry of the United States Department of Agriculture. So far as is known there are no data indicating that sewage effluents can be sterilized for less than $5 per million gallons. In fact, the studies by Mr. Geo. A. Johnson at Columbus on this subject seem to be the most extended. They indicated some doubt as to whether or not this price will give adequate treatment.

Chlorine and Hypochlorite. — Two interesting papers have recently appeared upon this subject, namely, "The Prevention of Bacterial Contamination of Streams and Oyster Beds," by W. Pollard Digby, F. S. S., A. M. I. Mech. E., A. M. Inst. C. E.,

and Henry C. H. Shenton, M. S. E., read before the Royal United Service Institution, December 3, 1906, and "The Sterilization of Sewage Filter Effluents," by Messrs. Phelps and Carpenter, in the last number of the *Technology Quarterly*, which was published about a month ago (January, 1907).

These papers contain many very interesting and suggestive statements as well as results of important original work.

It appears from this evidence that 50 parts per million of free chlorine when applied to a settled sewage effluent will produce sterility and that an application of 5 parts per million of free chlorine acting for a period of 2 hr. will remove materially more than 99 per cent. of the total bacteria and will practically eliminate intestinal bacteria as indicated by tests for B. coli.

Mr. Digby, who was connected as electrical engineer with the company which has developed the Woolf process in this country and England, has recently made important discoveries as to electrolytic cells for the decomposition of solutions of salt. Estimates of the cost per pound of available chlorine are given in the paper of Messrs. Digby and Shenton as ranging from 8.7 to 9.7 cents with electricity at 2 cents per kw-hr. and salt at $4 per ton.

Messrs. Phelps and Carpenter indicate in their paper that available chlorine can be manufactured for about 1.3 cents per lb., according to certain experiences in large paper mills using the McDonald electrolytic cell. Power is figured at 0.6 cents per kw-hr. with a production of 0.46 lb. of chlorine per kw-hr. On this basis it is stated that it would cost about 85 cents per million gallons to treat sewage effluents with 5 parts per million of free chlorine. It is believed that this figure is far below that which would be the actual cost in practice at most places, especially for plants of small or moderate size. In the first instance, coal is taken at $2 per ton, which is possible only in and near the coal regions. In the second place, the figures of Messrs. Phelps and Carpenter should be increased for charges for labor, both for generating power and for the application of the chlorine to the sewage effluent, interest on the capital investment for both power plant and treatment plant as well as the usual items for repairs, renewal and depreciation.

It is believed that the Digby and McDonald electrolytic cells note marked steps in advance along the line of improvements required for certain types of sewage disposal problems.

DISCUSSION.

Mr. R. Winthrop Pratt. — Mr. Fuller has in his paper mentioned the relation the State Board of Health has borne to the Columbus experiments. This Board has, from the beginning, kept in close touch with the city of Columbus in the various preliminary investigations and proposed schemes for sewage purification, and has endeavored to assist, educate and interest the citizens in regard to the problem. The unanimity of opinion among the people of Columbus as to spending the sum of $1 200 000 for sewage purification works was shown by the fact that this money was raised by popular vote requiring two-thirds majority.

The work which has been done at the Columbus Sewage Testing Station has been of great value to the State Board of Health in enabling it to point out to local officials the seriousness and importance of the question of sewage disposal, and to induce such officials to make suitable preliminary investigations of their own problems before spending any money in construction. While the experiments were in progress delegations from nearly every town in the state which was interested in the matter of sewage disposal made visits to the testing station.

After the experiments were concluded it was urged by some persons that it would be very desirable for the State Board of Health to continue the work at this station, and a movement was talked of to obtain the necessary legislation to enable this to be done. As the amount of money which the legislature would appropriate for work of the State Board of Health was known to be quite limited, it was thought on maturer consideration that the interest of a larger number of people would be served by making a series of studies of the various existing plants which are in operation in the state of Ohio.

With this in mind the Ohio legislature, in the spring of 1906, passed a bill directing the State Board of Health to make an investigation of the construction, methods of operation and the efficiency of all public water purification works and sewage purification works in this state, and made an appropriation to pay for this work. The investigation directed by the act was started immediately. Three additional assistant engineers were placed in the engineering department. Mr. A. Elliott Kimberly, formerly of the staff of the sewage testing station, was appointed special assistant engineer to conduct the field investigations relative to the various sewage plants.

The work under the above act up to date has proved of very great value. Not only has much information been obtained relative to the behavior of different types of sewage plants under different local conditions, but the officials in charge of the plants have become interested in the work and in several cases have improved and even remodeled their works, thus putting them on an efficient basis, whereas previous to our investigation they were useless. At four of the plants, where filters of coarse grain material are in use and where the practical test for efficiency is a non-putrescible effluent, we have arranged with the superintendents to make incubation tests daily of the effluent, and to keep full records of the principal features of operation of their plants.

The report on this work, including the water purification investigations, will be published about a year hence.

Referring to Mr. Fuller's discussion of the germicidal treatment of the effluent of coarse grain filters, I would say that for the last six months our department has been working coöperatively with the Bureau of Plant Industry, United States Department of Agriculture, in studying the effect of sterilizing the effluents from both coarse grain filters and from sand filters by the use of copper sulphate and also by the use of chloride of lime. The results of these studies will also be printed in the above-mentioned report.

Mr. Earle B. Phelps. — Mr. Fuller's paper contains such a wealth of valuable information and suggestion that any attempt to discuss it in full is out of the question. There are two subjects, however, which appeal to the writer somewhat more directly than the others, which will here be taken up, namely, sedimentation and sterilization.

The Columbus results undoubtedly embody the best experimental data on sedimentation thus far available. They indicate clearly the proper combination of the two important variables, time and velocity, for the most economical application of sedimentation to American sewages. Much confusion exists in the literature concerning the nature of the so-called colloids in sewage. Physically the colloidal state represents a condition intermediate between solution and suspension. Colloids will not settle out, neither can they be filtered out to any extent by filter paper. In this respect they are identical with dissolved substances. They differ from the latter in their inability to diffuse through animal or other membranes such as parchment, parchment paper or collodion.

In addition to true colloid, there is in sewage a considerable amount of material which is so finely divided that it will never settle owing to the resistance of the liquid. This resistance is not strictly a simple function of the downward velocity, for if it were all particles heavier than the liquid would settle, but is the sum of a velocity function plus a fixed resistance. Hence if the pull of gravity is less than the fixed resistance no motion results. It is strictly analogous to "starting friction." Since the resistance is a function of the viscosity of the liquid, it is natural that in sewage there should be found a considerable amount of material which will not settle but is nevertheless not colloidal. This point has been particularly studied to determine the relative amounts of this non-settling suspended matter in raw and septic sewages. After the regular determination of the suspended solids a chloroformed sample was allowed to settle for 4 days and the suspended solids again determined in the supernatant. The average results of this study, covering a period of 15 weeks, and involving the analysis of 15 samples of each kind, are here given.

Table of Suspended Solids Before and After Four-Day Sedimentation Period.

AVERAGES. PARTS PER MILLION.

	Initial.		Final.	
	Total.	Loss on Ignition.	Total.	Loss on Ignition.
Raw sewage	134	40	41	30
Septic sewage,	72	16	22	20

It appears, therefore, that there are in raw Boston sewage about 41 parts of suspended solids (non-colloidal), which will not settle out in 4 days, and that the action of the septic tank reduces this amount by 50 per cent.

In regard to chemical sterilization, the writer is in full accord with Mr. Fuller in his views on the importance of this method of treatment. Of all the various disinfectants which have been proposed, compounds of copper and of chlorine alone bear promise of practicability, and it is believed that the latter will ultimately be found to be the more suitable. Even if it should develop that the cost-efficiency of these two classes of disinfectants is at present about equal, the fact that copper is a commodity of limited supply and ever-increasing demand, making it probable that the cost of copper treatment will increase year by year, while chlorine is unlimited in supply and ever decreasing in cost with improved methods of manufacture, strongly favors the latter.

Mr. Fuller expresses the view that certain estimates made by this writer on the cost of manufacturing chlorine electrolytically are far below what would be the actual cost in most places. Two separate points are here involved; first, the cost of electric power; and second, the cost of manufacturing chlorine from salt by the use of electricity.

Electric power was figured at 0.6 cents per kw-hr., this figure being based upon the use of run-of-the-mine bituminous coal at $2.00 per ton. English estimates, by Digby and Shenton, referred to by Mr. Fuller, are 2 cents per kw-hr. At Salem, Mass., electric power is purchased after pumping sewage at 1.25 cents per kw-hr. Data on the actual cost of production are not readily obtainable. That the writer's estimates are not far from actual figures may be seen by a comparison of the cost of pumping water, a process at least no more economical than the production of electric current. At the Chestnut Hill high-service pumping station of the Metropolitan Water Works the actual cost for the year was 0.58 cents per h. p. hour, or 0.78 cents per kw-hr., coal costing $3.91 per ton. At $2.00 per ton the cost would have been 0.59 cents per kw-hr.

The estimate of 0.6 cents per kw-hr., exclusive of fixed charges, is, therefore, not unreasonably low, although admittedly it is based upon the results obtainable only with a plant of considerable size (300 kw.) and with cheap fuel. In the final calculation an additional sum of 0.3 cents was allowed to provide for a $50 000 power plant, which, it is believed, will also allow for some increase in the cost of fuel.

As to the cost of manufacturing chlorine electrolytically, our point must be made perfectly clear. The writer's proposal to use electrolytic chlorine, or bleaching powder prepared from chlorine, is entirely distinct from the various English processes and the older American Woolf process. These latter make hypochlorites, or oxychlorides as they are often called, in one operation, the actual result being obtained at great sacrifice in efficiency. On the other hand, free gaseous chlorine can be made at much greater efficiency per pound of available chlorine, and the writer is convinced can also be used more efficiently. From this chlorine bleaching powder can be prepared if so desired. English bleach is sold in the American market in competition with the home-product at a price which makes the available chlorine cost 2.5 cents per pound, or less than one third the estimated cost of chlorine in the so-called oxychloride form. This serves to indicate the relative efficiency of the two processes.

The use of free chlorine, prepared at the disposal works, would effect a saving of at least the cost of lime and the extra cost of preparing, marketing and shipping bleaching powder. Since the latter can be bought at 2.5 cents per pound of available chlorine, it seems a very conservative claim that electrolytic chlorine can be prepared for 2 cents. On this basis the cost of chlorine for sterilizing effluents with 5 parts per million would be 83 cents per million gallons. These statements apply only to those works whose requirements would warrant the installation of the necessary chlorine and power plant, or where cheap power is already available. For smaller towns, also, where municipal electric lighting and power stations are already installed, the manufacture of chlorine could be undertaken at reasonable cost. Elsewhere the purchase of bleaching powder would be found most advantageous. At current Boston prices the use of bleach would increase the cost of chemicals to $1.05 per million gallons of effluent.

Thus far nothing has been said about the valuable by-products of the electrolytic process, caustic soda, which is not obtained in the English processes. This would be produced in an amount practically equal to the amount of chlorine manufactured. Being used extensively in the soap industry, it would always find a ready local market, and its value would to a large extent offset the cost of the process. If it could be used without concentration, just as it leaves the chlorine plant, a great economy could be effected. Such a result could be brought about by the establishment of a soap works in the near vicinity. Under such conditions the value of the caustic soda would almost pay the cost of manufacture of the chlorine.

It will be of interest to compare the cost of supplementary sand filtration at Baltimore, as estimated by the Board of Advisory Engineers, with a liberal estimate of the cost of sterilizing the same effluents. To avoid debatable ground, it will be assumed that bleaching powder will be used at the market price. The sedimentation basins provided for in the plans for trickling filters make it unnecessary to add any special treatment works except a suitable mixing chamber and tanks for the preparation of the bleaching powder solutions. The entire plant could be run by three extra laborers in connection with the main works. A small amount of power would be necessary for the mixing devices. The estimate for sand filters does not include the cost of the 100 acres of land necessary, while the estimate for sterilization can undoubtedly be reduced by the manufacture of chlorine on the premises.

TABLE.

Comparison of the estimated costs of treating 75 000 000 gal. per day of trickling filter effluent at Baltimore by (*A*) supplementary sand filtration and (B) sterilization with bleaching powder, applying 5 parts per million of available chlorine.:

	A	*B*
Construction	$1 040 750	$25 000
3 per cent. interest	$31 221	$750
10 per cent. depreciation	......	2 500
Annual operation	55 000	35 000
Total cost per annum	$86 221	$38 250
Cost per million gallons	$3 15	$1 40

MR. JOHN W. ALVORD. — The paper of Mr. Geo. W. Fuller, embodying as it does not only a review of the work done at the Columbus Testing Station but also the matured opinion of the author upon the results secured, is of particular interest and value.

That portion of the paper dealing with the septic or sedimentation tank acquires a new interest from the recent decision in the New York courts in the Saratoga Springs case on the validity of certain patents connected with the septic tank. Undoubtedly that opinion will be appealed from, but in the meantime a very comprehensive opinion of the court in the matter would seem to foreshadow a favorable result from the point of view of the general public.

The writer, having been connected with the original investigation at Columbus in 1898, referred to in Mr. Fuller's paper, has taken especial interest in the solution of the problem in that city. It may not be uninteresting to review briefly the condition of the art at the time this first report was undertaken. Sewage disposal science was at that time in progress of rapid evolution, or one might almost say, revolution, — a revolution, indeed, quite foreseen by those favored few who had been working along bacteriological lines, but which by the general public, and even by the greater portion of the sanitary engineering profession, was not fully understood.

Sewage purification in America was limited to an understanding of intermittent filtration as developed and practiced in Massachusetts; also to that type of minor septic plants so happily worked out by Colonel Waring for the disposal of house

wastes, and chemical precipitation which had been developed in England, and, in connection with land disposal as a final stage, was generally supposed to represent the best attainable practice of the day for the larger class of problems. In certain favored localities we had broad irrigation, and sewage farms had their advocates. Some combinations of all of these forms of sewage treatment, together with minor use of tankage, were about all the available methods open to conservative consideration for the solution of the problem at Columbus, with its flow of something like 10 000 000 gal. of sewage per day.

Under such circumstances the study was undertaken with a full realization of the difficulty and magnitude of the problem. A prior inspection of European sewage purification plants had brought familiarity with the difficulties encountered abroad, and the undertaking was seen to be an intricate problem at the best. At this time, too, there was not a full understanding of the difficulty of applying intermittent filtration, as successfully practiced in Massachusetts, to the different topographical and soil conditions of the central West.

Intermittent filtration, broad irrigation and chemical precipitation were studied. Sedimentation and tankage were at first not thought applicable on so large a scale. During the investigation there was published in England Professor Dibden's book on the experiments with coke contact beds at London; this was an illuminating help, but at the same time a somewhat embarrassing one, as it unsettled the question of the available methods.

About the same time there was published in the *Engineering News*, for the first time in this country, a description of the septic tank at Exeter, which seemed to show that tankage was applicable to the larger problems. The similarity of the Exeter septic tank to the domestic installations of Waring in this country did not escape attention, but it was felt that to enlarge this application of tankage to the dimensions required by the Columbus problem would involve radical recommendations in new and untried fields. On the other hand, the experiments of Professor Dibden with coke breeze filter seemed to follow logically in many ways those experiments of the Massachusetts State Board of Health upon coarse grain filters which had been previously made.

Percolating filters at this time were, of course, quite unthought of. More embarrassing conditions could hardly now be conceived than those which confronted an engineer studying a

large proposition at this transitional period. On the one hand, if he escape the evils of undue conservatism by adopting in some form the newer methods, he might escape the imputation of being behind the times, but, on the other hand, he might easily fall into the difficulty of having recommended that which later on might be found to be absurd.

The establishment of an experimental station was thought to be impracticable under the laws then in force. The only arrangement which seemed to be possible under the circumstances was to suggest a conclusion which should be definite, and then proceed in such a cautious and experimental way that the result would be ascertained in advance of the main expenditure. Thus arose the peculiar conditions which resulted in outlining the entire plant, with the provision that a small portion of it should first be constructed and carefully studied. With these precautions it was deemed not too rash to recommend coke breeze filters or contact beds, as they would now be called.

The septic tank, as glowingly described, with its new and unfamiliar title, was passed over with such favorable comment as might insure a possibility of change of opinions either way. The report at the time it was published was criticised as extremely rash, and so much was said about the improbable schemes from England that found willing believers that no one could be humanly blamed for later enjoying the complete conversion of the critics, one after another. It was the first report that had been made in this country on the newer biological processes for any considerable problem, and seems unduly conservative in the light of later developments. In looking it over the writer is amused at the agility with which he climbed up on the fence over some questions and remained there to watch events; but better men have found themselves in the same predicament. Perhaps the greatest mistake of the report was that it did not stand out more strongly for adequate experimental work in the face of the legal and financial restrictions which then surrounded the city's action.

The rapid introduction of tanks for preliminary treatment of sewage in the central West gave that section of the country perhaps earlier knowledge as to the characteristics which should govern and control their management. The writer's first septic tank, as such, was constructed in 1898, and in the first season's observation of its working he formed some of the ideas which have since been fully developed elsewhere and largely approved.

These relate specifically to the fact that sewage varies greatly from time to time in character, in strength and in temperature; that these variations retard or accelerate the septic action, and that, therefore, tanks should be provided with compartments by which means the flow could be controlled so as to be adjusted to the character of the sewage which was to be treated.

The approval which Mr. Fuller has shown in his paper of this idea is peculiarly gratifying, because it is the one small feature which the writer has fondly hoped would be his contribution to the art. The control idea, not long since emphasized by Stoddart, of England, in his paper on the "Tankage of Sewage," has not ceased to have its value, though it may be admitted it is not necessarily so delicate an adjustment as was first thought.

The multiplication of sewage plants with preliminary treatment in tank has been very rapid, especially in the West. The writer has lost count of even the important installations that have been put into operation. It is a common experience in traveling to meet with plants of which there has been no published description. A large number of intelligent sanitary engineers are now working in this field, and their work is increasingly valuable.

Most of the Western experience has been gained by close observation of full-sized working plants rather than by laboratory experience or analysis, and it has not been our good fortune until recently to obtain from any source funds sufficient for careful and extended bacteriological and chemical investigation even of full-sized working plants, but this difficulty has been offset to some extent by the opportunities afforded to see so many plants working under varied conditions. The deductions drawn from these conclusions, while not always capable of being stated in the exact language of the analyst, are nevertheless most valuable information to those who have the opportunity to acquire them. It is, therefore, gratifying that practice based on such observation has been reduced to exact statement by the careful and accurate methods of the Columbus tests.

The writer agrees fully with what Mr. Fuller has said about the desirability of septic tanks being so operated as to not produce a greatly decomposed effluent. The liquids of sewage are usually susceptible to immediate filtration. It is the solids which it is desirable to detain and to break down by septic action; therefore the details of the tank should be so arranged that they accomplish the full retention of the solids, including,

where possible, all the lightest suspended matter, and yet facilitate the rapid passage of the liquid through the tank. This principle did not occur to the writer in connection with his earlier tanks, but of late has occasioned him much thought, and it is believed that there is room for important future development along this line. Suggestions made by Stoddart in England are for the separation of the inflow into two parts, the one containing the least suspended solids to be passed rapidly to the final compartment of the tank near its outlet, while that portion containing most of the suspended solids passes to a more prolonged rest.

The writer's attempts at a solution of the difficulty have come about in the design of a so-called circular decantation tank, a description of which may be of interest here. This is best shown in the design for a sewage purification plant for Bloomington, Ind. (10 000 population). The incoming sewage flow is admitted upward in the center of the tank; suitable circular baffles and walls impeded its progress radially outward so as to retain the heavier solids in the central compartment as much as possible. As many concentric baffles and walls may be introduced as seem desirable. The outflow from the tank and through the circular baffles is made practically uniform throughout their entire circumference. In this way slow radial outflow is everywhere developed in the tank, yet leaving the passage of the liquid from inlet to outlet with a comparatively short path. Means for regulating the diffusion of the sewage from the central inlet may be introduced in the circumferential outlets. The compartment system can be retained so that the effective capacity may be adjusted to the flow in the same manner as in the rectangular form of tank. This form, as a minor consideration, lends itself to economical construction, and the central compartment is capable of being flushed out through the inlet by suitable valves without emptying the remainder of the tank.

The further purification of the sewage may be effected by a radial dosing chamber or contact bed as part of the circular form, thus reducing the length of carrier or distribution pipe to a point compatible with reasonable elasticity of control. Great compactness is thus secured for the entire arrangement, and a minimum of land will be found necessary for the purpose.

The writer has been impressed for some years with the desirability of discovering means for retaining the finer suspended matter within the tank and preventing the unnecessary

enlargement of filters due to clogging. It is suggested that with the circular form of septic tank, here illustrated, this might be accomplished in larger plants where attendance was necessary by some form of strainer, either of hay or excelsior, which could be inserted in the numerous small outlets or overflows in the outer rim of the tank, the filtering medium being renewed from time to time as necessary. The amount of such strainer material might not be unreasonable, and ought to effect considerable mechanical clarification.

Another suggestion for this problem lies in utilizing roughing filters between the septic tank and the final filtration. This is, of course, only practicable where the first cost and operating expense of such filter is considerably less than the excess area of final filtration necessary. Such roughing filters might proceed along the line of those employed in Philadelphia in water filtration, or they may be built in the form of combined contact bed and dosing chamber; practically they are rapid rate contact beds, with contact material coarser than is usually used. Suppose that some form of honeycomb structure could be adopted in these roughing filters so that the voids, instead of being 30 to 40 per cent., as will be the case of stone or other material of like nature, could be raised to 60 or 70 per cent., as would be the case were they filled with farm tile or with hollow building tile, or even with brick laid up loosely. This idea has been suggested by Professor Dibden, and he calls such filters multiple surface filters, because the contact surfaces are retained to a large extent, while the voids are largely increased. It should be expected that such filters as these might be preferably worked at a very high rate and remain without clogging for a long time; perhaps seven to ten million gal. per acre per day would be practicable. Where trickling filters or intermittent sand filters are to follow the septic tank the substitution of an intermediate stage allows the combination of a rough contact filter and the dosing tank to good advantage. Thus in the Bloomington, Ind., plant shown this combination is effected. Rates for this so-called honeycomb contact dosing chamber are placed at 7 000 000 gal. per acre per day; and should it not prove as practicable as is hoped, the filtering material may be used elsewhere and the chamber used either as a dosing chamber or added to the septic tank capacity.

This is one of the experimental methods necessary for progress in actual practice which, however, does not involve appreciable waste of funds. It would be interesting if some of

our eastern experiment stations would undertake to demonstrate these ideas and give us some accurate statement of what is possible along this line.

The percolating filter is now the favorite design for the central West, where some dilution can be obtained for the effluent. Where high degree of purity is demanded, intermittent sand filters at such comparatively high rates as 0.2 to 0.4 million gal. per acre per day are considered essential and furnish an effluent of high class.

Even where sand is abundantly found in place the percolating filter is often the more economic installation. Preliminary studies for the sewage plant for the United States Steel Company's new city at Gary, Ind., have shown this to a remarkable degree. This enterprise, situated at the southerly end of Lake Michigan, is developing a mill site covering 1.5 sq. miles on the lake shore, and a town site of 2 sq. miles completely developed, with all city improvements. The water supply is derived from Lake Michigan, and of necessity the sewage will all ultimately have to be purified before emptying it into the Calumet River. The soil underlying and surrounding this new city consists of lake shore sand to a depth of nearly forty feet, yet preliminary studies have shown that percolating filters built of broken stone, brought from a considerable distance, will compare favorably in cost with intermittent sand filtration as a final stage. The deciding factor here is largely the cost of the land, which has rapidly increased in value in that vicinity. But even with cheap land, this sand in place does not indicate marked advantage for intermittent filtration treatment unless the highest purity of effluent is necessary.

It is interesting to call attention to the revolution in ideas which has come about through some of the newer biological processes. We formerly used to hear much about sewers of deposit, and it was thought egregiously bad practice to construct large sewers with stagnant or sluggish flow, as they would then become a menace to the health of the community by breeding disease in their midst. This thought seems to be passing away.

In constructing the main sewer for the new city of Gary there has been the necessity of building for a large future area not now settled. It has been suggested that the actual construction of the sewage purification plant for this district may be postponed to some extent by utilizing a portion of this main sewer as a septic tank for the earlier years, there being con-

siderable dilution available both from ground water and at the outlet in Calumet River. Accordingly plans have been prepared for damming the outlet of this sewer to a sufficient height to slow down the flow to a point which will be desirable for septic purposes, or a retention which will correspond to 6 or 8 hr. rest. It is thought that this will afford relief for some time to come. It is evident that, if successful, this suggests a new use for large unemployed outlet sewers, and is further suggestive as to possibilities of permanent application.

Mr. Fuller's paper draws out the interesting fact that the problem of sewage purification is increasingly easier with the more diluted sewages. It has been noted by the writer repeatedly that a system of separate sewers intended to receive only the household waste, but which, through inadvertence or ignorance has been allowed to receive some portion of the rainfall, has unexpectedly resulted in favorable operation of the sewage purification plant. Indeed, the introduction of a considerable and not unreasonable amount of pure water to a septic tank often facilitates its work. Evidently the reason for this is that the toxic effects of over-septicized liquid are removed for the time being, and if the added water is not so great in amount that suspended matter is washed into the effluent, the process is beneficial. The addition of considerable ground water into the separate systems of sewerage is not always to be dreaded, and the resulting necessity of caring for it in the sewage purification plant is often the occasion of much needless solicitude. It is a matter of common knowledge that the most difficult problems which confront the sanitary engineer are those in which no dilution water enters the sewers, and the resulting concentrated sewage is, as a consequence, found to be exceedingly difficult to purify.

In general, the sewage of the larger towns and cities, with its more even flow and uniform character, presents the least difficulties in purification, while the most difficult problems in domestic sewage are the small institutions with scant water supply and no available dilution for effluents.

Mr. A. Elliott Kimberly. — As possibly of some interest in connection with Mr. Fuller's admirable review of the Columbus sewage data, the writer desires to present a few views regarding the advantage of flexibility in the design and operation of septic tanks.

While the subsidence of sewage in septic tanks exerts the well-known equalizing effect upon the character of the incoming

sewage, yet, of course, at times of wet weather and during drought, wide variation is remarked in the composition of the resulting effluent. Depending upon the quantity and the character of the raw sewage, the actual period of subsidence required for maximum suspended matter removal varies widely, and under these conditions a septic tank arranged with several compartments affords many advantages from the operating standpoint.

During high flows the flexible plant allows the operator to employ a greater tank capacity, thereby overcoming in part the effect of the increased flow by permitting the linear velocity to be maintained more closely to the normal for the given sewage. Without the option of increasing the tank capacity during such periods under the increased velocity the suspended matters may be imperfectly removed, and sludge deposited under ordinary flow conditions may be scoured out, both features tending to clog the oxidizing devices to which the sewage is then applied.

Another feature obtaining in a non-elastic layout during high flows is that while the total feet of travel may cause a normal removal of suspended matters, yet the zone of heaviest deposition is thus transferred to a point nearer the outlet, and as soon as decomposition begins in the sludge deposit the rising and falling sludge may in part be carried out with the effluent since less opportunity is afforded for the subsidence of the suspended matters that are introduced into the sewage as it passes over the point of maximum sludge deposition and decomposition. Extending the views of Mr. Fuller with reference to a thorough screening of the sewage before septic treatment, the writer believes it to be important to restrict the deposition of the coarse suspended matters to the inlet half of the tank so that the comparatively greater fermentative action of the coarse matters may not detract from the efficiency of the tank by virtue of their deposition too near the outlet to admit of their retention until so reduced by bacterial action that they form a part of the thoroughly hydrolized deposit of sludge. The well-known "blow-up" periods in septic tanks of course cause large quantities of suspended matters to escape from the tanks, to the great detriment of the filters, and some efforts have been made to overcome this damaging feature by the use of screens, scrubbers or strainers, but so far as the writer is aware none of these straining devices has been entirely successful in practice. A septic tank on the compartment plan, however, especially one

in which there may be obtained a tandem effect, would appear to be going far toward the prevention of clogging in filters in cases where subsidence forms a part of the preparatory treatment to which the applied sewage is subjected.

Mr. F. A. Barbour. — The present contribution of Mr. Fuller is a most welcome addition to the literature of sewage disposal, not only as a summary of the valuable series of experiments made at Columbus, Ohio, but as an unusually frank and confidential statement of the author's personal interpretation of these experiments in the light of present-day information. Carried out on a large scale, the work at Columbus has unquestionably placed high-rate methods on a better foundation than ever before in this country.

The history of sewage purification, starting with the adoption of the water carriage system, runs through the periods of irrigation and chemical precipitation in English practice to the time of the Massachusetts experiments, by which the underlying chemical and bacterial agencies were first clearly outlined, and intermittent sand filtration made for New England the recognized method of disposal. English engineers not having sand but appreciating the bacterial and chemical reactions proved by the Massachusetts work to be essential to success, proceeded to utilize this knowledge in the development of various high-rate processes, such as contact beds and sprinkling filters. Numerous plants of these types were constructed, and it is to England that, during the past ten years, we must look for the greatest progress in sewage disposal work. Some high-rate plants, largely based on English results, have been built in this country, but a series of experiments such as those at Columbus was most desirable for a better understanding of the processes involved and as a demonstration of the adaptability of such methods to the temperature conditions of this country.

The direct practical outcome of the Columbus work has been the adoption of the septic process and sprinkling filters — in some cases followed by sand filtration — at a number of the largest disposal plants yet undertaken in this country. The feeling of the writer is that a long step forward has been taken in this present appreciation of these more intensified processes but that some conservatism may not be amiss in the adoption of rates of operation and perhaps in the use of such methods, except where high-class supervision is assured. In saying this the value of good design and the possibility of discounting many troubles in operation thereby are thoroughly appreciated,

but it is believed that the more highly developed the process the more intelligent must be the supervision of the plant. In the case of very large works where the magnitude of the undertaking will of itself insure good maintenance, it will be possible to operate all parts of the plant at high efficiency, but in small works the exigencies of average municipal managements must be given consideration. Personally the writer feels strongly on this question of disposal works maintenance. A plant entirely successful under one management will, with a change of authority, by politics or otherwise, rapidly go to the bad through neglect, and the most simple and that which will stand the greatest abuse has much to recommend it. Perhaps the more obvious requirement of careful management in the case of high-rate plants will insure a better standard of maintenance than has been generally given to the disposal works already constructed in this country and so justify the use of such methods even in the smaller installations. In the light of experience, however, the writer is inclined to discount the possibility of maintaining small sprinkling filters at the same efficiency and operating rate as may be reasonably adopted in large installations.

The time has, however, unquestionably arrived when the use of these higher-rate processes must be given consideration in the working out of any problem, whether it be in Massachusetts or the Middle West. Where sand is economically obtainable, intermittent filtration is probably the safest method for the average community; but lifting of the sewage to considerable heights through long force mains in order to reach such material can be justified only after a careful examination and rejection, for cause other than conservatism, of these other methods.

The recognition of the septic process as a valuable preparatory treatment by the Columbus work is a source of satisfaction to the writer. Since 1900, in all plants constructed by him outside of the state of Massachusetts, this has been a part of the scheme of disposal, and in all cases with results which have justified its use. Thus far fortune has favored these plants apparently in furnishing the necessary bacteria without special seeding, but why some work better than others cannot be determined from the period of septic exposure or the chemical characteristics of the sewage. As Mr. Fuller states, there is much to be done by bacteriologists and it is to be hoped that in some of these larger plants to be constructed it may be possible to work out the causes not now understood of relative success or failure in septic work.

The writer agrees that septic treatment does not enable higher rates of filtration to be maintained other than as the amount of suspended matter is reduced in the sewage by its use. Its value lies in the economy or necessity of removing as much of the solids before filtration as may be physically possible and in the subsequent liquefaction of a portion of the intercepted solids, thus reducing the amount of sludge to be handled. In the experience of the writer the deposit, which may from time to time require removal from septic tanks, is less obnoxious than the ordinary sludge from settling tanks emptied at intervals of a few weeks. The validity of this statement depends entirely on the premise that the tanks are working properly. It is not necessary that the septic process should liquefy all the solid matters retained in order to justify its use. As to how much screening is advisable, this depends on the collecting system of sewers. With a separate system and no abnormal manufacturing conditions, if the inlet of the septic tanks is so designed as to distribute the solids over the surface area of the tanks, it is believed that only coarse screening is necessary.

Despite the present popularity of sprinkling filters, contact beds will probably continue to hold a place in disposal practice. This method has the advantages of requiring less height for its installation, of being better adapted to low temperature conditions and of being more sightly and less liable to the creation of odors during the application of sewage than sprinkling filters. It is well adapted for institutional and small municipal work where sand filters cannot be economically used. In such work, where plants must be located comparatively near dwellings, a contact bed filled from below has particular advantages in absence from odors and in the fact that it may be operated without the sewage appearing in sight at any stage of the process.

Such application of sewage suggests a query as to the relative value of the anaerobic and aerobic periods in contact work. While sprinkling filters are an oxidizing process throughout, contact beds alternate between anaerobic and aerobic conditions. When filled from above, the sewage, if well distributed, trickles over the particles of the bed and for the time being partakes of the action of the regular sprinkling filter. While without proof by actual comparative analyses, the writer has believed that the distribution of the septic effluent over the bed surface and this trickling action during the filling of the bed have been of some value in the contact beds at Mansfield, Ohio.

In sprinkling filter work the method of applying the sewage

is the factor most essential to success. The writer believes that with present knowledge it is advisable to so arrange the dosing apparatus that the liquid may be applied continuously under a constant head, or intermittently through a dosing tank, discharging at short intervals, with a variation in head on the nozzle such that the spraying radius will be changed so as to practically cover the entire area of the bed. This is the arrangement proposed for West Chester, Pa., in plans submitted last year, which involve the use of septic tanks, sprinkling filters and finally sand filtration.

One of the most interesting features of the Columbus work is the unequivocal statement that a non-putrescible effluent is sufficient for local conditions, and the statement that while some disease germs may travel the intervening miles to the nearest water supply, the difficulty of purifying the water will not be materially increased. Such a conclusion is based on the premise that no river of any size running through an inhabited territory can be maintained at a drinking standard and that all surface water should be purified before use. This being accepted, no material damage is done to the riparian owners if an effluent of such degree as to not appreciably add to the difficulty of purifying the water is turned out. Personally the writer believes this to be a reasonable position and that by the adoption of such rational standard greater sanitary progress will be effected than through any attempt to reach the impossible ideal of maintaining rivers in anything approaching their original purity. There is, however, always something to be gained by setting a standard high and there is danger in any official or formal acceptance of a certain degree of inevitable pollution. It may be entirely reasonable, but it seems a cold-blooded proposition, to discharge the septic sludge into the Scioto during periods of flood flow. Perhaps the dilution is sufficient to prevent a nuisance and there may be but few disease germs in the decomposed sludge, but it would seem that by its discharge an additional and unnecessary burden is thrown on possible users of the water below. Merely from a politic standpoint provision for the disposal of this sludge in some other manner might have been a good investment.

The rights of riparian owners in such a case are of general interest. At the present time all manner of opinions and standards are being maintained. Recently in New Brunswick the board of health and the provincial government refused to sanction the discharge of the sewage of 6 000 people into a river with 14 000 sq. miles of watershed and no public water supply

within 80 miles of the point of discharge. The river water, without this sewage, is unfit for domestic use, and apparently the entire decision was based on the common-law rights of the riparian owners to receive the water "as it is wont by nature," or as near that condition as it can be maintained by preventing the obvious discharge of sewage through artificial structures. Testimony as to what is being done in other parts of the world had apparently little effect upon the authorities, and the position taken is that now and before contamination has become great is the time to prevent pollution of rivers so far as may be done through reasonable governmental control. Such position is very different from the intention to discharge septic sludge into a river of but a small fraction of the size of that to which reference is made. In any case of stream pollution, as in the case of the contamination of shell fish, a reasonable balancing of the cost of obtaining higher degrees of purity in effluents with the importance of the interests affected should be the governing condition, but what about the legal rights of such interests? It is not always necessary that damage capable of demonstration by analysis or sensuous evidence should be done in order that the damage be material.

Prof. C.-E. A. Winslow. — Mr. Fuller's admirable review of the current art of sewage treatment furnishes new evidence of the remarkable progress in this branch of engineering which has marked the last few years in the United States. Since the original experiments of the Massachusetts State Board of Health, which laid the foundation for the whole science of sewage disposal by biological methods, the most important developments along this line have been made by English engineers; now, once more, American practice promises to occupy in some phases of the subject a position of international leadership.

In regard to the removal of suspended solids, in particular, the Columbus results are unique in completeness and precision, Mr. Fuller's discussion of the septic tank and its working seem also deserving of special comment. This device is rightly treated as simply a sedimentation tank in which part of the deposited sludge is liquefied, the action of the tank upon the liquid itself being harmful rather than beneficial. Emphasis is well placed, too, on the importance of the specific bacteria concerned in the septic process as offering a possible explanation for the marked differences observed in practice between the operation of different septic tanks. The fact that hydrogen sulphide is not formed from the sulphates in the Columbus sewage

is somewhat surprising. In the septic tanks at the Technology experiment station, large amounts of hydrogen sulphide are produced by the septic process. It is very possible, as Mr. Fuller suggests, that the organisms which carry out this decomposition are absent from Columbus sewage. In Boston sewage all conditions seem right for the most efficient septic action. For two successive periods of two years each, septic tanks have been operated at the Technology experiment station without serious sludging. In the first period 0.60 cu. yd. of sludge were deposited in the tanks per million gallons of sewage treated, as against 2.68 cu. yd. at Columbus. Before septic treatment at Boston, 0.65 cu. yd. of detritus per million gallons are taken out by a screen and grit chamber.

The only point at which I should take serious issue with Mr. Fuller is in regard to the bacterial purification effected by biological processes. He says in one place, "The removal of bacteria in sedimentation or septic tanks seems to approximate that of the total suspended matter, as shown from the data obtained from comparatively small sewage settling basins and from numerous water settling basins. Bacterial growths of certain species within a septic tank frequently obscure this general statement, which is intended to apply especially to those bacteria originally present in the sewage, and particularly the pathogenic bacteria."

Again, in speaking of trickling filters, he says that the bacterial removal "at Columbus was about 70 per cent. of those in the applied liquid, and it is estimated to be about 90 per cent. when compared with the bacteria in the original sewage. These results obtained with 5-ft. beds would be much higher with deeper beds. The Lawrence data indicate that there would be a total removal of from 95 to 97 per cent. with 10-ft. filters."

Messrs. Hering, Fuller and Stearns based their Baltimore plans upon a similar supposition that "the removal of bacteria by the septic tanks, sprinkling filters and settling basins is in the neighborhood of 95 per cent. of the number contained in the original sewage."

Certain of these assumptions are not justified by any experimental data with which I am familiar. The total bacterial removal effected at Columbus, comparing trickling effluent with crude sewage, varied from 30 per cent. to 80 per cent., and the view that the removal of sewage bacteria is greater than this is apparently founded on the analysis of four samples only. On the other hand, Houston's elaborate studies in England led him

to the conclusion that "the different kinds of bacteria and their abundance appear to be very much the same in the effluents as in the crude sewage," and he found that in no case was the reduction of B. coli and other sewage forms "so marked as to be very material from the point of view of the epidemiologist." Our own results at the Technology station agree fairly well with those of Houston. For two years we have been treating Boston sewage from the main interceptor of the South Metropolitan District on two outdoor trickling beds, each 25 sq. ft. in area and 8 ft. deep, filled with 2-in. stone. One filter takes crude sewage and the other the effluent from an 8-hr. septic treatment in a tank divided into five successive compartments. The effluent from the filter which receives septic effluent is subsequently settled for 2 hr. in a conical tank of a modified Dortmund pattern. Bacterial analyses have been carried out for a year now and the average results for the last 6 months of 1906 are tabulated below. Each figure represents the average of 37 to 40 analyses.

BACTERIA IN BOSTON SEWAGE AND EFFLUENTS.

Averages for July–December, 1906.

	Total Bacteria per Cu. Cm. Gelatine at 20°.		Presumptive Test for B. Coli. Lactose Bile at 37°. Per Cent. Positive Results in .000001 Cu. Cm.	
	No.	Per Cent. Purif.	Per Cent.	Per Cent. Purif.
Crude sewage,	970 000		35	
Effluent from trickling filter,	300 000	69	29	17
Effluent from septic tank,	780 000	20	47	Increase
Effluent from septic tank and trickling filter,	260 000	73	32	8
Effluent from septic tank, trickling filter and sedimentation tank,	340 000	65	27*	92

* In .00001 cu. cm.

As in the Columbus experiments, the trickling filter alone produced about 70 per cent. removal of total bacteria; the gas-forming organisms, however, which probably represent in a general way the B. coli group, were reduced not more, but less, than the total number. In the septic tank, too, while the total bacteria decreased 20 per cent., the gas formers actually multiplied. Septic treatment followed by trickling filtration reduced the total bacteria by 73 per cent. and the gas-formers by only 32 per cent. Subsequent sedimentation, however, did show a

selective action, increasing the total numbers from 73 per cent. of the sewage value to 65 per cent., but greatly diminishing the gas-formers so as to produce a net purification of 92 per cent. Here there was no doubt a large removal of the bacteria in the effluent, accompanied by a multiplication in which the B. coli group did not take part.

In these experiments it does not appear that the intestinal organisms, of which those which give gas in the lactose-bile medium are certainly fairly representative, decrease more rapidly than the total bacteria, but the reverse. They actually multiplied in the septic tank and held their own better than the average of the bacteria in the trickling filter. Sedimentation did, however, produce a large reduction in these experiments.

One may be inclined to guess that typhoid bacilli would decrease faster than the bile-fermenting organisms in septic tanks and trickling beds, but the guess is too vague to be made the basis for quantitative statements of efficiency or for the construction of sewage disposal plants. It is very questionable whether much reliance should be placed on septic tanks and trickling filters for bacterial purification. Sedimentation alone would probably be relied upon by few. These devices are excellently adapted to the ends for which they were designed, the removal and oxidation of organic matter. Often this is all that can be required of a sewage disposal plant. When bacterial purification is also required, it seems probable that subsequent filtration or sterilization must be combined with them.

Mr. F. Herbert Snow. — Speaking generally, the principles of bacteriological processes of sewage purification are so well understood by experts and proven in a few cases in practice, both in Europe and America, that it is unnecessary in a majority of cases where the problem of sewage disposal other than into a stream or body of water must be taken up by a municipality, to go to the trouble of making tests to determine what kind of works shall be adopted. If this were not true, rapid progress in the discontinuance of the discharge of sewage into the waters of a state should not be hoped for, because of the expense involved in conducting conclusive tests. Fortunately the larger municipalities mentioned by Mr. Fuller and the state of Massachusetts have done this work and given the results to the world at large. The Columbus experiments materially add to the knowledge on the subject from the American standpoint.

However, the real essence of the sewage disposal problem, the application of known principles to practice under varying

conditions, has not become so thoroughly understood that inexperienced engineers can tackle any project which may come along with reasonable assurance of unqualified success. Evidence of this fact is manifest in the numerous failures of sewage disposal plants in small communities. Since those best qualified by experience and actual knowledge often approach the solution of a sewage disposal problem with apprehension, surely others should hesitate to make recommendations. There is no work of public utility demanding more careful and experienced consideration than this very one of sewage treatment. It is peculiarly at this time in the development of the art a specialist's problem. No municipal engineer should attempt to solve the problem without the services of a competent consulting expert.

State supervision and approval of plans may help some towards satisfactory results, and should secure them, but it is not good public policy for the state to do much more than advise and direct. The initiative and the burden of responsibility in choosing and putting in force the means with which to bring about the general policy of a commonwealth respecting stream pollution properly belong to the local authorities. And in this work economy and efficiency demand expert service outside of that which the state should render.

In Pennsylvania the largest city has over 1 000 000 population. There are several hundred small incorporated boroughs scattered all over the state. From the standpoint of public health it is relatively more important that the sewage of these small places should be treated. Many of them are foci of infection of water supply; so marked diminution in water-borne diseases cannot be accomplished unless attention be given to the treatment of the sewage there.

The question of preliminary treatment of sewage or the correct capacity for tanks, sand or other filters, where the total cost of the plant is to be from \$25 000 to \$50 000, is easily within the grasp of an engineer versed in the subject. There is not enough leeway in expenditures to warrant tests to determine the merits of design. Of infinitely more importance are simplicity of design and the fact as to whether the sewers of the town receive sewage only or sewage and storm water. An expert's advice on what should be done where the sewers are on the combined plan may easily save to the municipality more than his entire fee.

Preparatory treatments are of vital importance to the continued success of a plant, more especially if the sewage be a

manufactural one or conspicuously characterized by the inimical wastes of some one industry. It is not safe to put the stamp of approval on plans unless facts as to the quality of the sewage have been given due consideration. Here again the expert is needed.

At present some disposal works are designed to obviate a nuisance in a stream, and where this is the object the problem is different from the other case where the object is to prevent pathogenic poisoning of a public water supply. Disease germs should be killed, if not in the dwelling, then as soon as possible. Barriers against them should be set up all along the line, and it should not be possible for them to run the gauntlet and live to poison the water we drink and the food we eat. Some day it will not be a question in designing a sewage disposal plant whether it will take out 70 or 90 per cent. of the danger and poison, but whether the germs have been completely killed. To-day it is not practicable from the dollar standpoint to accomplish such a result, but it will be in the future. This thought should not be cast aside, but well may influence the location and general layout of sewage disposal works now.

In considering preliminary treatments each process has its advantages and advocates. For instance, strainers are often proposed. While their operation is expensive, yet good results may be obtained thereby, and if economy is not to be the criterion, then the strainers must be accepted. Here again does the value to the municipality of the consulting engineer come into play. The state should not necessarily condemn a process simply because it is expensive, while the consulting engineer upon whom the responsibility of balancing the design rests would withhold approval of a needlessly expensive apparatus.

Plain sedimentation is an efficient preliminary process, but it is not to be preferred to the septic tank for hygienic reasons alone, if for nothing more. Yet plain sedimentation is bound to play an important part, either alone or in modified form in the future. The expert should be consulted.

The septic tank is the most important preliminary treatment because of its hygienic utility. Its value in small towns is enhanced because the minimum of attention is demanded by it. Another great value is the fact that disease germs perish readily and in greater numbers in the septic tank. Its value as a sludge liquidizer is uncertain and depends to a considerable extent upon design, sewage flow and intelligent operation.

The generally accepted opinion that the successful operation

of a septic tank is assured, once the structure is erected, is far from the truth as proved by experience. Mr. Fuller aptly says, "It is not to any practical degree helpful for subsequent filtration, except in so far as the original sewage is clarified by visible means." In other words, plain sedimentation is as advantageous for subsequent filtration. It is the writer's opinion that septic tank operation may be harmful to subsequent filtration, and he sees no reason to change former oft-repeated statements to the effect that the general application of the septic tank process by the hit-or-miss plan should be discountenanced.

There is much to be explained in accounting for the successful reduction of sludge in some tanks and the comparatively unsuccessful reduction of sludge in other tanks. Here is a field of research for the state authorities who maintain a supervision over the operation of a plant which has received prior state approval of design.

In this connection each new disposal works is a testing station, and in time, aided by the right kind of local coöperation and management, the benefits of supervision by the state of all such plants within its jurisdiction will bring compensating values far-reaching in all directions.

In the management of sewage disposal works there will be demanded in the near future specially trained men, and this field is commended to student engineers.

Mr. Fuller's conviction that "a septic tank should be designed with various compartments so that portions may be used from time to time and other portions temporarily thrown out of use," is most earnestly seconded. For a municipality, no matter how small the plant, it is desirable that at least two compartments be provided in the tank.

Whether or not odors will emanate from a septic tank or the disposal works is largely to be proven on trial. There may or may not be odors. Whether they will be objectionable depends primarily upon proximity of dwellings or a much-traveled highway. It is good practice to isolate the plant. How remote it should be is a local question. Upon this point the state authorities must deliberate. It is right there that a difference of opinion may arise between local and central officials. Whether the state would be a party to the defense in litigation for injury to property by reason of a nuisance created by a sewage disposal plant, the plans of which were approved by and the operation conducted under supervision of the state, is not the question. State approval should mean something. The condition of ap-

proval should vouchsafe to the general public, in the interests of public health, proper location and design, efficient management, operation and maintenance. It is a fact that these things cannot be brought about generally independent of state authority.

Intermittent sand filtration, in some instances, even at a higher cost, is desirable where good efficiency is required. This applies particularly to small plants liable to receive the minimum of attention, where, therefore, sprinkling filters or contact beds would be useless. A sand filter can stand more neglect and abuse than any other and still give fair results. In fact, instead of the Massachusetts intermittent sand filter being a thing of the past, the writer concurs with Mr. Fuller's opinion that it is destined to continue to serve a very useful purpose.

Contact filters invite failure more, however, on account of negligent operation than otherwise. Where this process is peculiarly suitable, there is no reason appearing at present why it should not be sanctioned. Mr. Fuller thinks contact filters may be advantageously installed in those instances where they can be used without pumping and where pumping would be required for sprinkling filters. If this were to be the principal determining factor, we should witness in the future the erection of more contact filters than those of any other kind.

The writer views with apprehension the non-conservative willingness of municipal engineers generally to recommend sprinkling filters for every kind of a sewage purification task. Here is an old principle newly applied with little to look to by way of practice, and with much to be observed and learned therefrom, and yet the method is being rashly recommended. The danger of failure is greatest with the smaller plants. Only where works of this kind are of a magnitude sufficient to insure proper management should they be adopted for the present.

The plan of building a tentative installation, or a small part of the disposal works as designed in its entirety, whereby tests can be made in practical every day-week management and results noted as a basis for modification of details for extensions to complete the entire works, is a commendable one and is being fostered in Pennsylvania.

The germicidal treatment of coarse-grain filter effluents will be required more and more in different parts of America until an impetus shall have been given to research that shall result in developing efficient and economical methods.

The setting up of state standards of purification, except in individual cases, is a mistake. What is impractical of attain-

ment to-day in the degree of purification may be easily within reach and desirable to-morrow. Work should be designed and so constructed, if possible, that advantage may be taken of advancement in knowledge when the time for extension of any plant arrives. Above all, state oversight of management of sewage purification works is demanded in the interests of sanitation and good judgment.

Mr. Clyde Potts. — The writer has read Mr. Fuller's paper with much interest and believes the data presented and the clearness of its presentation are potent factors in the evolution of the art of sewage disposal.

There are several points touched on in the paper which are not related to the data given, but which must be apparent to every engineer who has to deal with sewage disposal. They are:

1. — Is it necessary to seed the tanks with proper bacteria to insure successful septic action?

2. — How much truth is there in the theory of bacterial antagonism?

3. — The feasibility of designing a septic tank so that the decomposed sludge may be separated from the decomposing and thus disposed of without creating a nuisance.

On the first point the writer is inclined to agree with Mr. Fuller that the failure of certain septic tanks does not seem to be satisfactorily accounted for except that they are not inoculated with the proper bacteria.

In regard to the third point of the difficulty of properly designing a septic tank. This is a real one. Septic action in tanks as they are now designed is a continuous operation. It is never completed. When sludge is drawn off it is taken from a process of fermentation that is still active. It is like removing the ashes from a fire that still burns. Some of the sludge is wholly decomposed and some still decomposing. Some of the sludge has been decomposed for months and some is recently decomposed. Do sludge tanks as used in England and recently proposed for this country remedy this?

Not only is the sludge drawn from a tank where the fermentation is still active, but the septic tank effluent is likewise still undergoing changes.

In a septic tank it is supposed that the activities are lessened as the outlet is approached; that all the beneficial results are accomplished during the progression through the tank. If a tank is mechanically perfect this may be so. With increased flow progress through the tank is hastened and with the night

flow it is retarded. The deposit of sludge varies with temperature, and consequently the cross section of the tank varies, and with it the velocity of flow. Even in a separate system the sewage flow varies also with rainfall owing to the infiltration. To be mechanically perfect a septic tank should accommodate itself to these variable factors. It is needless to say few tanks do and hence the difficulty.

Another point Mr. Fuller makes is illustrated in Table 5 of the paper, where the comparative costs of different methods of treatment for the Calumet area south of Chicago are given as follows:

Sand filters	$28 383 000
Contact filters	22 807 500
Sprinkling filters	17 637 500

This is cited as an argument for sprinkling filters being preferable to sand filters. The writer is by no means certain that the different methods of disposal above outlined are comparable, inasmuch as the character of the effluents is not comparable. For the conditions at Chicago undoubtedly either of these methods would give a proper effluent, and for Chicago they would be comparable, but where the effluent is to be turned into potable water, or into waters inhabitated by shellfish, would not the quality of the effluent have a commercial value not considered in Table 5? To make the data comparable for a general statement, the quality of the effluent should be considered and the cost expressed in terms of its character. In fact, where the highest practicable degree of purification is demanded, the economies involved would then be reduced to the question, How many acres of sand filters would sprinkling filters as a preliminary treatment save? In such a case sprinkling filters would only be considered as a preparatory treatment.

There is no doubt sprinkling filters possess great advantages over other types, especially contact beds, and mark an advance in sewage disposal, but whether they solve all the difficulties of filtration can be better determined after the Columbus filters are put in actual operation. In the development of the sprinkling filter, the work at Columbus will long stand as a classic. One is impressed with the fine technical character of the work done, and most of all with the vast amount accomplished with so small an outlay of money.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by November 1, 1907, for publication in a subsequent number of the Journal.]

Editors reprinting articles from this Journal are requested to credit the author, the Journal of the Association, and the Society before which such articles were read.

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MODERN POWER STATION AND ELECTRICAL CONSTRUCTION.

By W. A. Haller.

[Read before Louisiana Engineering Society at its meeting, May 13, 1907.]

In designing a power station and distributing system the first matter to be taken into consideration is the character of service, whether for street railway, lighting, power or for other uses. At the present stage of development nearly every city and town is using electrical energy to a greater or less extent; therefore the designer of a new installation may obtain some kind of data which will be found useful in calculating the present or future requirements as to capacity or kind of service. In the absence of any such data, however, reasonably close estimates may be made on a per-capita basis, although this ratio varies in different localities, the variation being particularly pronounced between northern and southern cities.

Heretofore the most difficult problem before the engineer has been the selection of a type of electrical apparatus which would come nearest to supplying all classes of service, the principal of which have been:

1. 550-volt direct current for railway use.
2. 2300-volt alternating current for lighting use.
3. One of the three or four methods of supplying arc service.
4. Commercial power service; 110–220 or 500 volts direct current or alternating current.
5. Three-wire direct current Edison service for light and power.

In the past, three or four and sometimes all of the different kinds of current have had to be generated in the same station,

each requiring a different form of generator or apparatus, which has rendered the station design difficult and the proper relaying of apparatus almost impossible.

The above remarks, of course, apply to stations supplying all the different classes of service required in any community, as under the conditions formerly existing in this city.

The present stage of development of electrical apparatus enables the designer to install one type of prime mover, or, at the most, two types for all classes of service. The most modern and commonly used is the steam turbine, and this paper will bear largely on the construction features pertaining to the in-

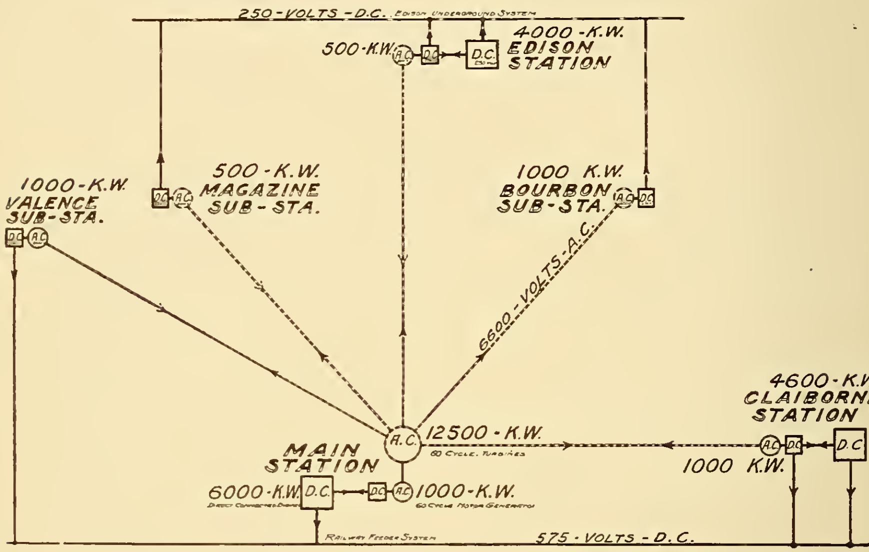


FIG. 1. ELECTRICAL CONNECTIONS OF STEAM STATIONS AND GENERATING SUB-STATION.

stallation of turbo generators and their supplementary apparatus. Note, however, that while the steam turbine, is the cheapest and most compact generator produced up to the present time, there are certain conditions under which reciprocating steam engines are still more economical. This would and does apply to the Claiborne power house installation in New Orleans, at which station reciprocating steam engines have recently been installed for the purpose of generating direct current for railway purposes.

The features influencing this were, first, that a considerable amount of 550-volt direct railway current is required at that location; second, condensing water of ample quantity is available;

third, the necessity for transmission lines and motor generators is obviated, except to a limited extent, thus keeping down interest and depreciation charges; fourth, less liability of interruption to service on account of fires or interruptions of service at central station; fifth, generating cost to deliver direct current to railway switchboard, taking interest and depreciation into consideration, is lower.

The New Orleans system, of which this paper is descriptive, consists of one central power generating station, four auxiliary steam stations (two of which will shortly be abandoned), three motor generator sub-stations, with others under contemplation. These are indicated on accompanying diagram, Fig. 1, showing electrical connections by which all of these stations, performing all classes of service, may be operated in parallel and by means of which any piece of apparatus in any of these stations may be made to perform any type of service required, through the medium of transformers and transmission lines, and still further all the stations may be tied together electrically and the loads thereon equalized.

Central Power Station.

The first station to be considered will be the central power station, located at Market and South Peters streets. The capacity of this station is given in the following table:

	Present Installation.	Ultimate Installation.
Electrical generators	17 800 kw.	50 000 kw.
Boilers	10 800 h.p.	30 000 h.p.
Coal bunker capacity	2 000 tons.	5 000 tons.
Equivalent capacity in 16 c.p. lamps	356 000	1 000 000
Approximate coal consumption per day,	200 tons.	500 tons.
Approximate condensing water required per day of 24 hr.	70 000 000 gal.	200 000 000 gal.

The engineering and construction features were conducted as follows: Designs, drawings and specifications were prepared in the New York office of Messrs. Sanderson & Porter, the engineers and constructors. The construction of the turbine station was carried on by a local superintendent, assisted as follows:

Mechanical engineers.
Electrical engineers.
Bookkeepers.
Paymasters.
Foremen, etc.

The actual construction of the station in question was commenced about August 1, 1904. The first new boilers went into commission about fifteen months after the commencement of construction work and the first turbine went into operation two years after commencement, and at this writing the initial construction is substantially complete.

The construction costs and records were kept as shown on the following form, each feature of construction being assigned a number, sub-classifications being used under each number. Labor costs and material costs were kept separately.

	Material.	Labor.	Total.
No. 1. Engineering,	....	....	....
No. 2. Pile driving,	....	....	....
No. 3. Earth, excavating and removal,	....	....	....
No. 4. Foundations,	....	....	....
No. 5. Intakes,	....	....	....
No. 6. Building,	....	....	....
No. 7. Boilers,	....	....	....
No. 8. Economizers,	....	....	....
No. 9. Stokers,	....	....	....
No. 10. Coal-handling machinery,	....	....	....
No. 11. Ash-handling machinery,	....	....	....
No. 12. Stacks,	....	....	....
No. 13. Piping,	....	....	....
No. 14. Pumps,	....	....	....
No. 15. Condensers,	....	....	....
No. 16. Turbines,	....	....	....
No. 17. Engines,	....	....	....
No. 18. Switchboard,	....	....	....
No. 19. Station wiring,	....	....	....
No. 20. Machine tools,	....	....	....
No. 21. Temporary job lighting,	....	....	....
No. 22. Liability insurance,	....	....	....
No. 23. Contractors' equipment and tool account,	....	....	....
No. 24. Temporary operating expenses chargeable to construction,	....	....	....

In addition to the above, several other miscellaneous classifications are used, dependent somewhat on the work in hand.

Pile Driving. — The central power station is supported entirely on piling, most of which was about 50 ft. in length, some of the piling being set to a depth of 30 ft. below surface, making a total penetration of 80 ft. Nearly all of the piling was placed approximately 3 ft. centers, making something like 4 000 round piles for the job.

The deep trenches and all other foundation limits were bounded by 6-in. grooved piling 30 to 50 ft. in length, 2 by 4 in. splines being used to insure alignment and tight joints. To successfully excavate to any great depth in New Orleans, the excavation must be protected by absolutely tight sheet piling and the bracing must be capable of resisting any pressures exerted on the sheeting by the surrounding earth. In the work, calculations were invariably based on the surrounding earth being of a liquid form and of approximately twice the density of water, or about 120 lb. per cubic foot.

Excavating and Earth Removal. — The total excavation amounted to about 8 500 yd., some of which was done by means of an orange peel digger, and the earth was removed by means of a tramway. Owing to the comparatively small volume of excavation, however, and the numerous obstructions, no very unusual success attended this feature other than that the progress of the work was much faster than could have been expected with carts and hand excavation.

Foundations. — The entire building is supported on a concrete mat approximately 6 ft. thick, reinforced in both directions with Ransome rods, the location of this reinforcing and the quantity thereof being dependent on the character and location of loads to be carried. The intake pipes pass under the boiler room at a considerable depth, and at this point the trench was back-filled wlth concrete.

The total load evenly distributed over the entire foundation is something less than 2 000 lb. per square foot, but the concentrated loads at certain points are very much in excess of that figure. These excess loads, however, are wholly or in part distributed by the concrete structure.

Intake Pipe. — The ultimate power-house development will call for four 72-in. conduits for condensing water. Two of these will be for the supply and two for the discharge. All four of these pipes have been installed through the levee, three have been installed under the boiler-room, but only one intake and one discharge have been installed in the open space between the boiler-room and the levee.

The above conduit is made up of riveted steel pipe 0.5 in. thick, made in 30-ft. lengths with flanged joints, lead gaskets being used between the flanges, and galvanized bolts being used to bolt the pipe together. All of this piping was dipped in hot compound after being completed, this compound adhering to the metal to a thickness of about $\frac{1}{16}$ in.

With a maximum velocity of 4 ft. per second it is estimated that the two pairs of conduits will handle sufficient condensing water to develop 50 000 kw.

Water jets have been installed throughout the entire length of this pipe, the purpose of which will be to assist in the removal of sand or silt which may be precipitated in the pipe. In addition to this a propeller type of circulating pump has been provided, this pump having a capacity sufficient to create a flow of from 8 to 10 ft. per second through the incoming and outgoing conduits. The valves used for closing off or sectionalizing this conduit are of the round balanced wicket type, as shown in Fig. 2.

Building. — The building above the foundation line, with the exception of window sash and frames, is composed of steel, brick, concrete and other non-combustible materials. The weights are supported entirely on a steel structure. The floors throughout are of concrete and the roof is partially of Ludowici tile and partially of book tile with composition top coating.

Boilers. — There are 12 Babcock & Wilcox boilers, each of 900 h.p. capacity (the largest ever built by that company). These are designed for 200 lb. working steam pressure and fitted with B. & W. bent tube superheaters designed to produce 150 degrees superheat under normal operation. The above boilers are arranged on the double deck plan, two rows on each deck, with the boilers facing.

Economizers. — One Sturtevant economizer, 10 tubes wide and 36 tubes long, containing approximately 5 400 sq. ft. of heating surface, is provided for each two boilers. These economizers are so arranged that the boiler gases may pass either directly to the stack or through the economizer.

Stokers. — The plant is equipped with thirty-six 300 h.p. Murphy smokeless furnaces, each 6 by 7 ft., set three in a battery under each boiler. These stokers project in front of the boilers and receive their supply of fuel by gravity from the overhead coal bunkers. The ashes and clinkers are passed through the bottom of the stoker (this motion being performed automatically) into ash hoppers directly under the furnaces. The demonstrated coal-burning capacity is 50 lb. per square foot of grate per hour.

Coal Handling. — The coal-handling plant consists of track scales, track hopper, mechanical feeder, crusher, elevator and belt conveyor. The coal as it is delivered is first weighed. It then passes on to the hopper and is dumped. It is then fed to

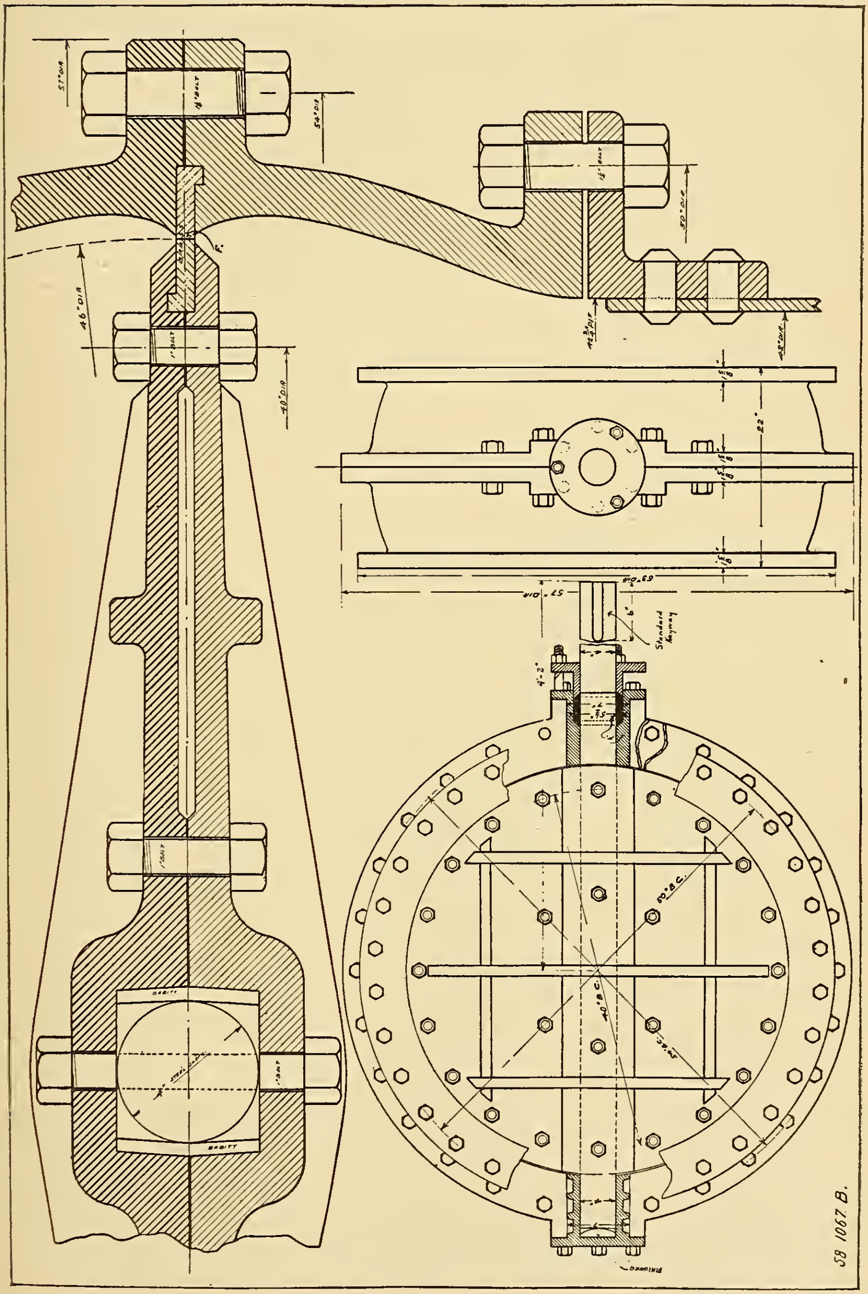


FIG. 2. WICKET VALVE.

the crusher by a mechanical feeder. It is then elevated to the top of the boiler-room structure and discharged on a belt conveyor traveling at 300 ft. per minute, which distributes it to any desired part of the coal bunker. The capacity of the coal-handling machinery is approximately 100 tons per hour.

Ash Handling. — The ashes pass from the ash hoppers under stokers down through spouts to cars operated on a tramway in the boiler-room basement. These cars are filled and then run to one end and dumped into an automatic skip which hoists them to the top of the boiler-room and discharges into an ash bunker directly above the railroad siding, from which they are removed either by cars or teams.

Stacks. — The plant is at present equipped with two self-supporting steel stacks, each 15 ft. in diameter by 273 ft. high above sidewalk level, brick lined to the roof line. The ultimate plant will call for the erection of two additional stacks of similar size.

Piping. — All high-pressure piping is full weight standard lap-welded mild steel with Van Stone joints. All fittings and valve bodies are made of cast steel and the valves have extra long necks at the stuffing boxes, designed for use with superheated steam at 200 lb. working pressure. The valves in main header and cross connections are motor operated. All boiler feed piping is of cast iron or brass and provision has been made for supplying any boiler from either of two sources.

Pumps. — Boiler feed pumps are of the Epping Carpenter make with compound steam ends, outside end packed plungers, pot valve type, designed for 250 lb. working pressure and equipped with automatic pressure-regulating governors.

Condensers. — There are at present installed one Alberger surface condenser on a 1 500 kw. turbine, two Alberger centrifugal pump jet condensers attached to two 1 500 kw. turbines and one Alberger centrifugal pump jet condenser connected to a 3 000 kw. turbine. These condensers are supplemented with dry vacuum pumps, and the equipment as a whole is designed to produce very high vacuum, this being essential, as turbines are dependent in a very great measure on high vacuum to secure economy.

Turbines. — The plant at present contains three 1 500 kw. Curtis turbines, one 3 000 kw. Curtis turbine, with one 5 000 kw. turbine of the same make on order. The above turbines are all alternating current, 60-cycle, three-phase, and are suitable for the generation of energy which may be used directly or indirectly for any service for which electricity is used.

Engines. — The station also contains two 2 250 kw. vertical engines and one 1 500 kw. vertical engine, all directly connected to railway generators. These engines have been in use for several years, and while they are operating in the same station with turbines, they may be considered the correct type of apparatus

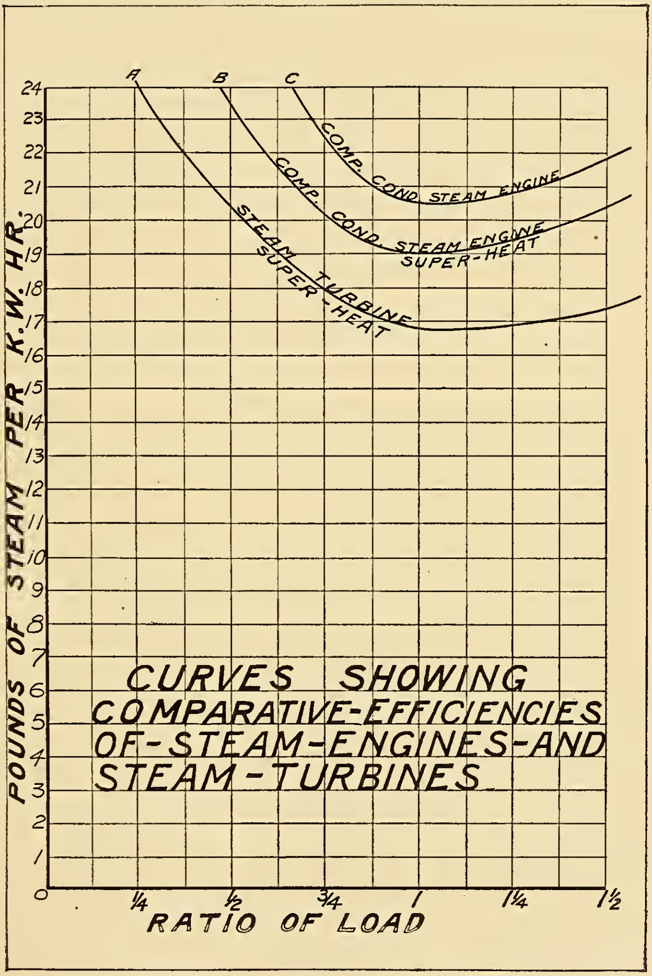


FIG. 3.

for the work they are doing. The energy could be produced by the turbines more cheaply, but that portion required for car operation would have to be transformed to direct current by means of motor generators or rotaries.

The relative economy of the steam engine and turbine is approximately indicated on accompanying chart, Fig. 3.

Switchboard. — The switchboard and control apparatus is of the most modern type. All high tension switches are of the oil-break type located in individual concrete cells and controlled from the main switchboard by means of pilot switches. The bus bars are in duplicate, in addition to which they are sectionalized. Each feeder circuit is provided with two switches, one switch connected to each set of bus bars, either one of which may be used to supply any circuit. In addition to this the principal power circuits are connected at the opposite end to either the Claiborne power station or the Baronne Street station, and in the event of an entire interruption of service at the main station these circuits may be supplied from either of these auxiliary stations, which arrangement insures the continuity and reliability of service to an unusual degree, without any expenditure for duplication of apparatus.

Claiborne Station.

The Claiborne Station as described herein consists of an extension to the old Claiborne Station, built about eight years ago, and is intended to generate current for the operation of the cars in the lower section of the city, and also as a distributing station for a. c. energy.

Pile Driving and Foundations. — This station is built on piling varying from 40 to 50 ft. in length, placed at approximately 4-ft. centers, except in certain locations, where the loads are comparatively light.

Some of this piling was set to a depth of 25 ft., but the majority of the foundation work of this station commences at about grade 27 (from 3 to 4 ft. below street level at that point). Six-inch grooved sheet piling was used to protect the deep excavations.

Intake. — The intake pipe for condensing water is 69 in. inside diameter, starts at the Southern Pacific ferry slip and terminates in the condenser pit at the power station, the center of this pipe being at grade 18.5. This pipe possesses a novel feature in that there is a creosoted wood diaphragm through the center of the pipe, the incoming water passing through the lower half and the discharge water going out through the upper half. A concrete crib was built just outside the levee, this being partitioned off to separate the incoming from the outgoing water. This structure is also used as a valve chamber, by which any one or all of the pipes terminating therein may be shut off.

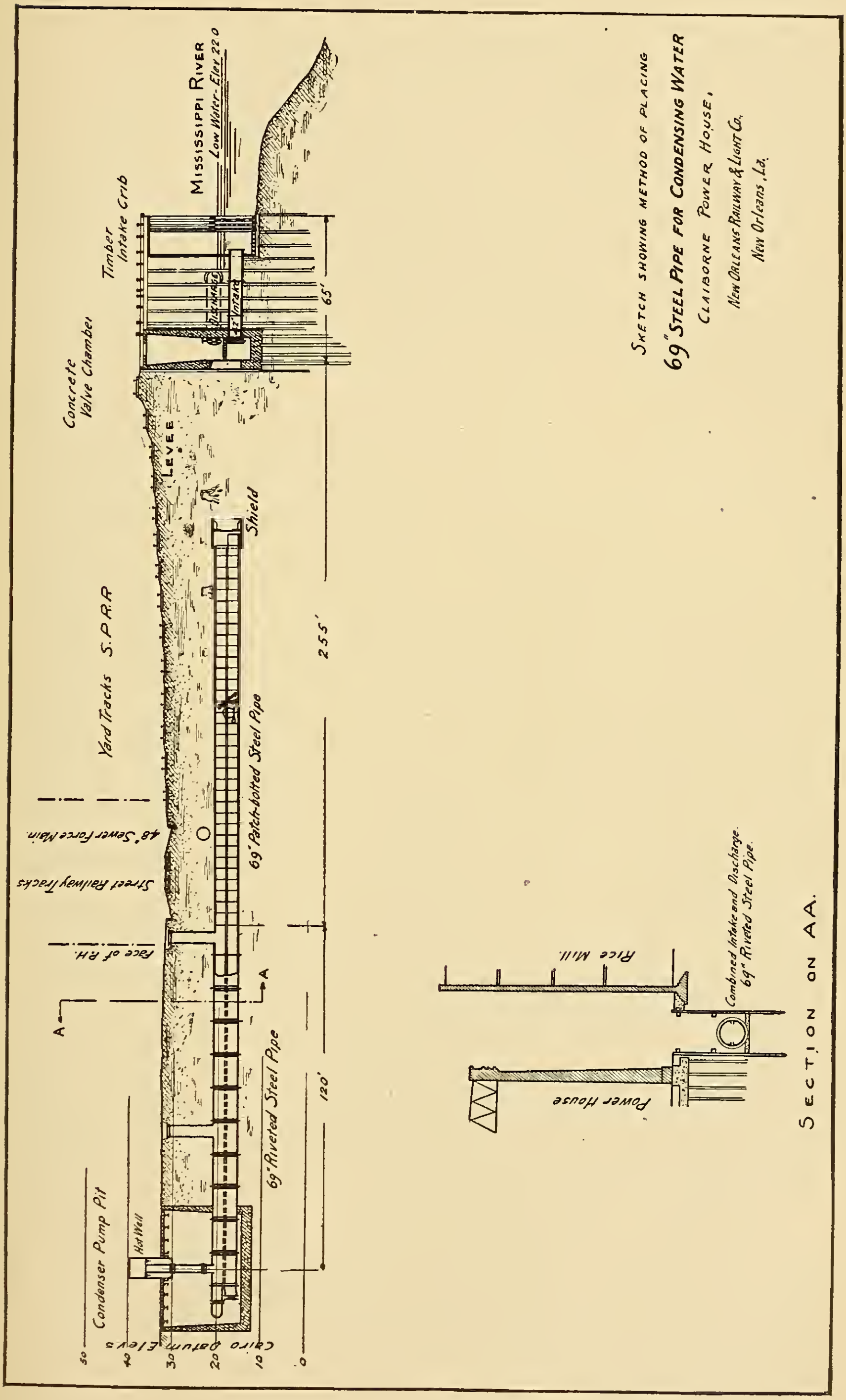

Sketch showing method of placing
69" Steel Pipe for Condensing Water
Claiborne Power House,
New Orleans Railway & Light Co.
New Orleans, La.
Mississippi River
Low Water - Elev. 22.0
Timber Intake Crib
Concrete Valve Chamber
Levee
Shield
Yard Tracks S.P.R.R.
48" Sewer Force Main.
Street Railway Tracks
Face of P.H.
69" Patch-bolted Steel Pipe
69" Riveted Steel Pipe
Condenser Pump Pit
Hot Well
Cairo Datum Elev's
65'
255'
120'
A
Rice Mill.
Power House
Combined Intake and Discharge.
69" Riveted Steel Pipe.
Section on AA.

Fig. 4.

The portion of the pipe from the condenser pit to the street line consists of 15-ft. sections bolted together by means of flanges, lead joints, etc. Commencing at the street line and passing under the street railway, the Southern Pacific tracks and other obstructions, the excavating was done by the shield method and the pipe was assembled in 5-ft. rings within the shield, there being no openings to the surface and no interruption to traffic overhead during construction.

The process of laying this pipe is illustrated in Fig. 4 and some of the details of the shield and sections of pipe are also shown. The intake and discharge as installed will supply sufficient water to condense the steam from about 15 000 h.p. engine capacity.

Excavating and Earth Removal. — The most of the excavation for the Claiborne Station was comparatively shallow and was therefore taken care of by hand, the material being transported away by carts. There was one excavation approximately 20 by 60 ft. in area and about 20 ft. deep, but the bracing and other obstructions rendered anything but hand excavating out of the question.

Stack. — The new stack for this station is 11 ft. in diameter by 175 ft. high. It is located directly in the center of the new portion of the power station and would also be directly in the center of the ultimate installation in the event of its being extended. This stack is of a novel design in that the stack base consists of four steel columns stiffened with concrete and brickwork and the space directly under the stack is arched over, leaving a large passageway both on the boiler-room floor and on the basement level. One other feature is that the bottom section of the stack is square instead of round, the side sheets being riveted directly between a channel framing at the base of the stack, there being no base ring. This construction is partially shown on Fig. 5.

Machinery Foundations. — The machinery foundations are entirely of concrete, built up in the usual manner, except, however, that large arches were provided under the engine cylinders, allowing ample room for access to piping and other parts beneath the engine-room floor.

Building. — The building is a combination steel, brick and concrete construction; the engine-room walls are entirely of brick and the crane runway and roof trusses are supported by the brickwork; considerable steel was used in the boiler-room, however, for supporting the coal bunker and economizers. A

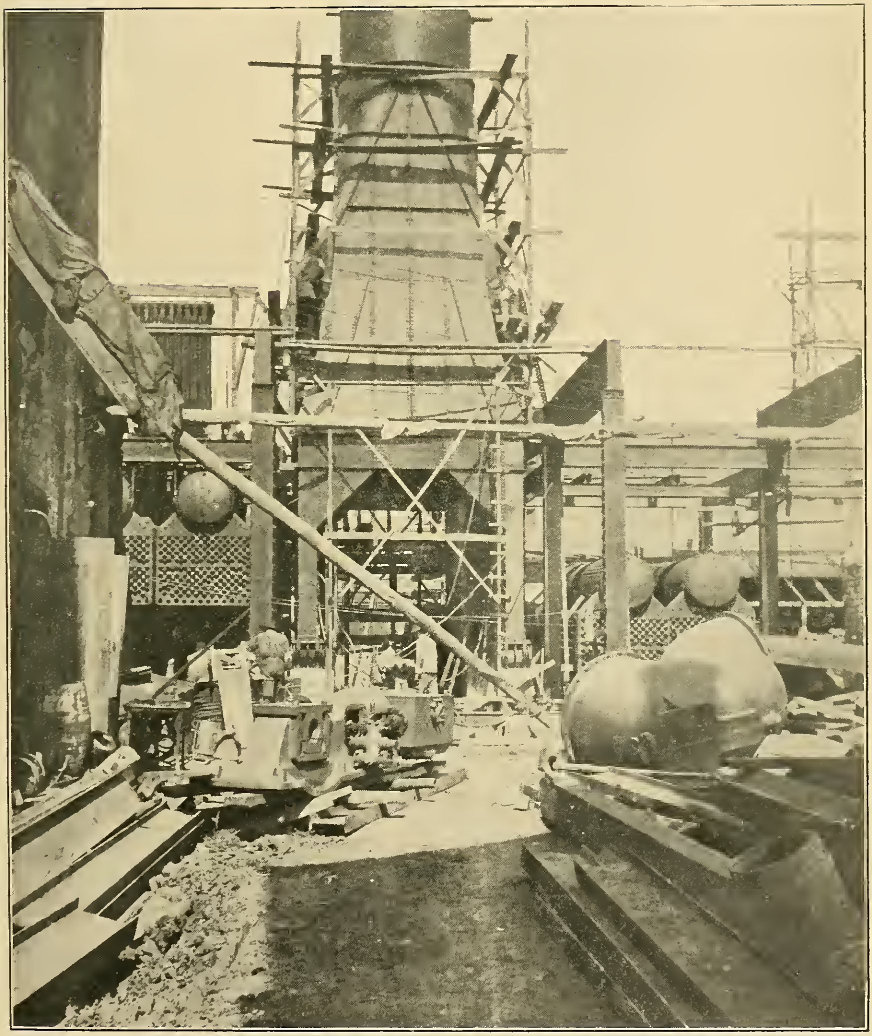
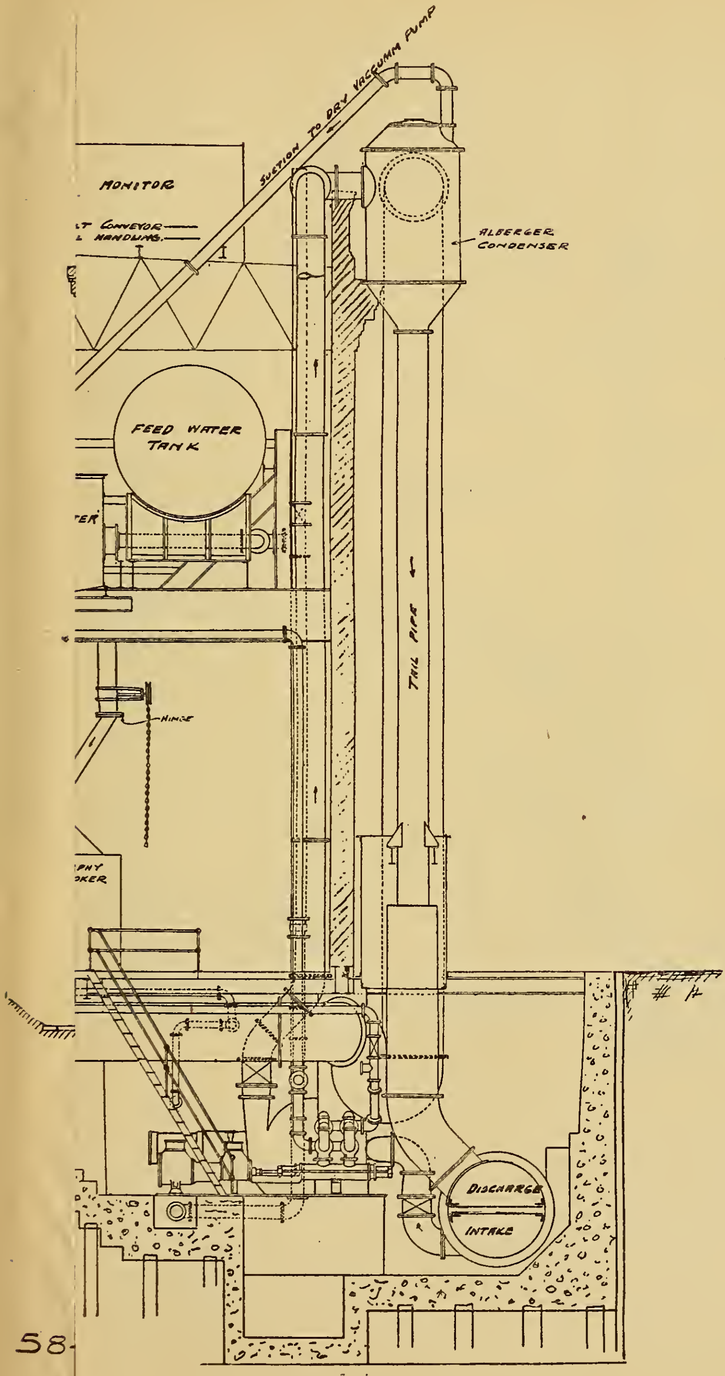


Fig. 5. Claiborne Stack Steel Work.


SUCTION TO DRY VACUUM PUMP
MONITOR
ALBERGER CONDENSER
FEED WATER TANK
HINGE
TAIL PIPE
DISCHARGE
INTAKE

58

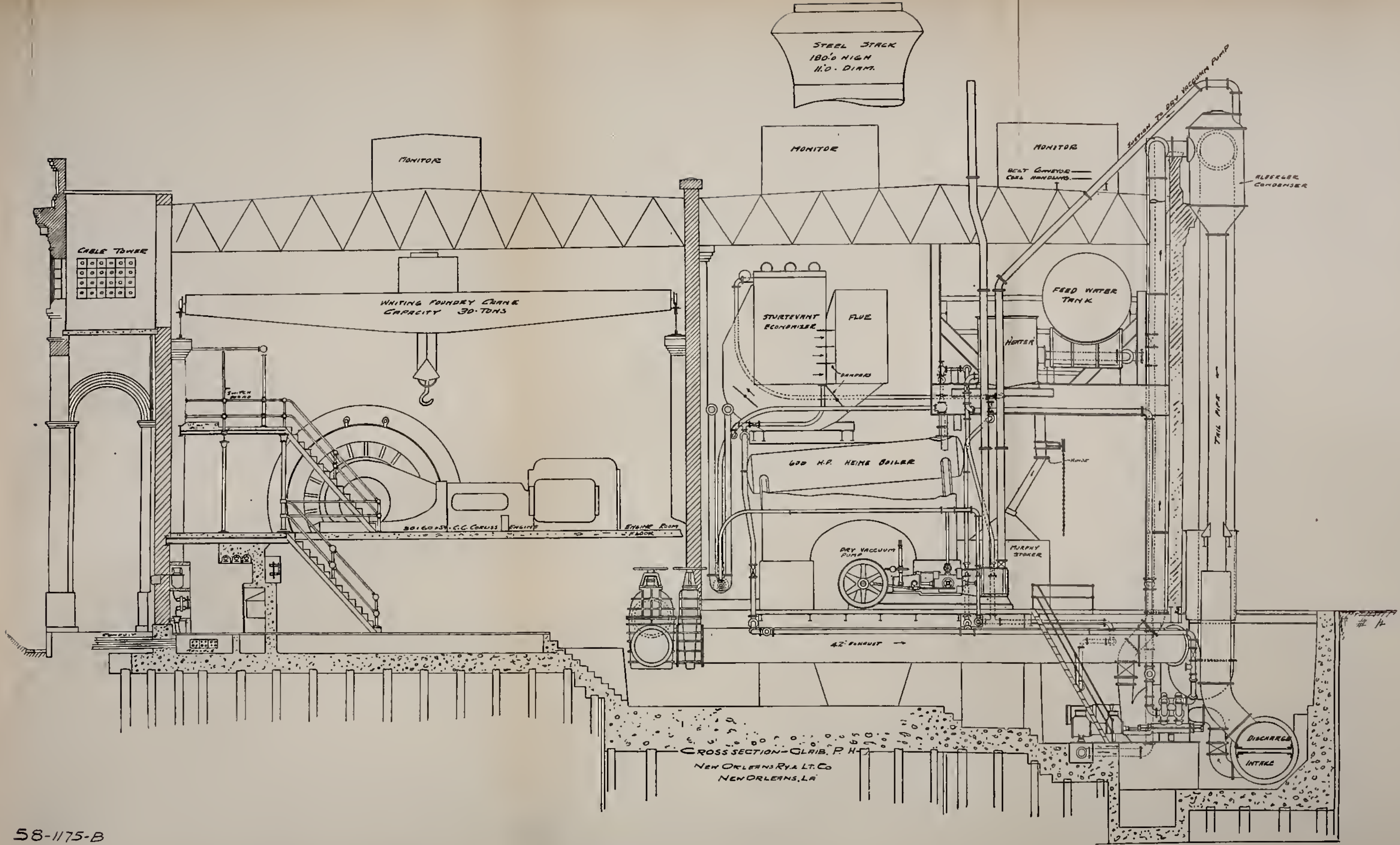
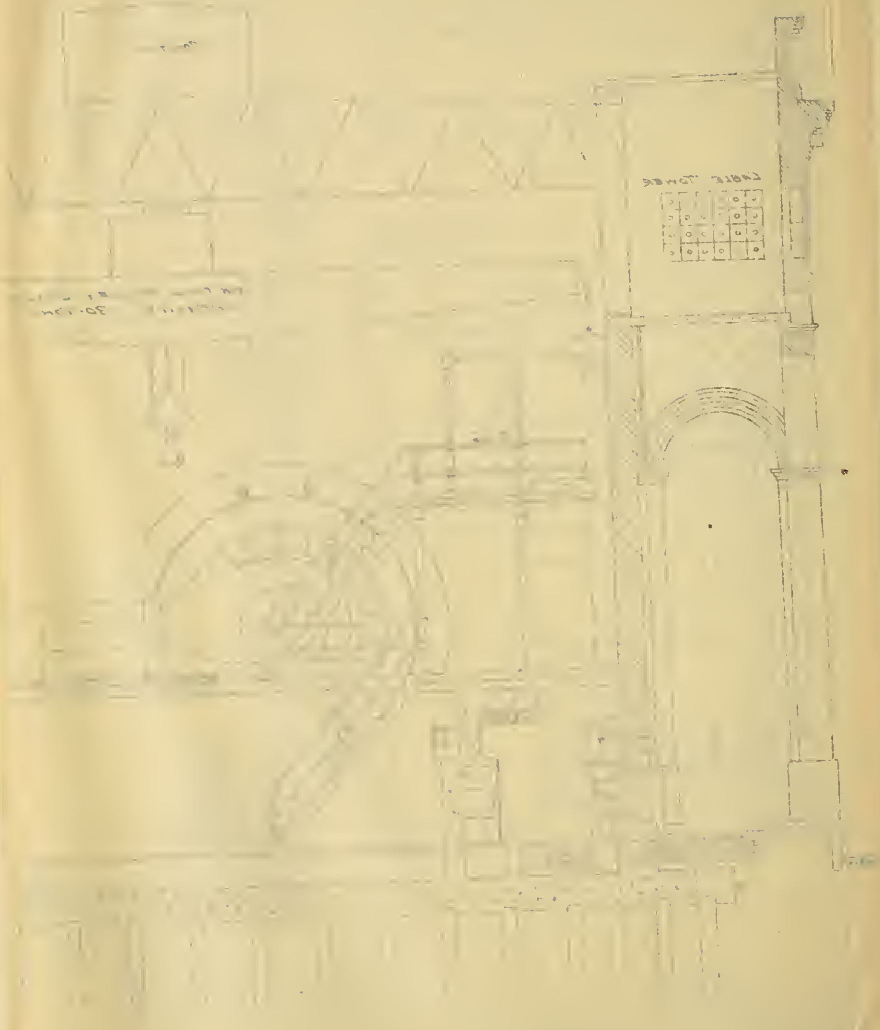


FIG. 6. CROSS SECTION THROUGH CLAIBORNE POWER HOUSE.



fair idea of the character of the building may be obtained from Fig. 6.

The floors are of concrete throughout; the roof is also of concrete, approximately 2.5 in. thick, with a 1-in. top coating. Both engine and boiler-room roofs have ventilating monitors throughout the entire length, and the section of boiler-room roof directly over the economizers has an additional monitor which provides a free circulation of air, a very desirable feature in this climate.

Both the outside and inside engine-room walls are faced with salmen pressed brick laid in cement mortar. There are no very notable features about the building other than that it may be considered an up-to-date example of its kind and admirably adapted to southern climatic conditions.

Boilers. — There are now installed in the station four Edgemore boilers of approximately 350 h.p. each and four Heine boilers of approximately 600 h.p.each, making a total of 3 800 h.p. These are arranged in a single row facing away from the engine-room.

Stokers. — Eight 6 by 8 ft. Murphy smokeless furnaces are installed in this station, these being under the new boilers only. The stokers are rated at 300 h.p. each, two stokers being used per boiler. The ratio of heating surface per foot of grate surface is approximately 60 to 1.

Coal Handling. — The coal is delivered to the station in wagons or carts, but it is intended that it shall be later delivered in cars and discharged directly into the crusher. After passing through the crusher, the coal is elevated in a continuous bucket elevator and discharged on a 24-in. traveling belt operating at a speed of about 200 ft. per minute, and by means of this belt distributed to any part of the coal bunker. The capacity of this equipment is about 50 tons per hour.

The coal, after being delivered into the bunker, passes down through spouts to the stoker hoppers and is fed through the stokers automatically.

Ash Handling. — The ashes drop directly into concrete hoppers located under the stokers and thence to a car and conveyed to one end of the boiler-room, at which point they will be elevated by means of a skip and discharged into an overhead bunker. The dust from the furnaces and the dust from the combustion chambers will be delivered into the ash hoppers by means of screw conveyors. Therefore there will be no occasion to handle coal, ashes or dust over the boiler-room floor.

Economizers. — The station is equipped with four Sturtevant economizers, one economizer being placed over each one of the four 600 h.p. boilers. These economizers are 12 tubes wide and 10 tubes long, giving an unusually large area for gas passages through the economizer. Dampers are so arranged that by means of interlocking mechanism the economizer may be cut in or out of service by throwing a lever from the boiler-room floor, and while a boiler and an economizer constitute a single unit, any economizer may be cut out without interfering with the use of the boiler, and the requisite feed water for all of the boilers may be passed through the remaining economizers in service.

Piping. — Full-weight standard lap-welded pipe was used throughout for high-pressure steam. Van Stone joints were also used for sizes 7 in. and larger.

The main header is 12 in. diameter, sectionalized and with boiler and engine connections so arranged that any section of header may be taken down for repairs without interfering with the use of any boiler or any engine.

An auxiliary steam line supplies steam to the boiler feed pumps, circulating pumps, etc., this line receiving its supply of steam from either battery of boilers or from the main header at the rear of the boilers. The boiler feed pipe is in duplicate and is cross connected with double crosses at several points so that both systems may operate simultaneously, one handling hot water and the other cold water, or with a number of combinations. This arrangement of piping is shown briefly on Fig. 7.

Oiling System. — The oiling system consists of overhead tanks supplying oil to the engines under a gravity head, the waste oil passing through the bearings, then to a filter located in the basement and from the filter to the overhead tanks, the original starting point.

Condenser. — The plant is equipped with a 42-in. elevated barometric condenser of the Alberger type, rated at 5 000 kw. capacity. The exhaust steam from all of the engines is conveyed to the condenser through a 42-in. exhaust header.

Circulating water is taken from the bottom half of the intake pipe previously referred to, and is passed through centrifugal pumps having a capacity of 5 000 gal. per minute against a 70-ft. static head. Two of these pumps are provided, each being driven by a 12 by 16 horizontal side crank engine fitted with hand-operated cut-off gear. This form of condenser, after being started, only requires that the water be delivered to the point

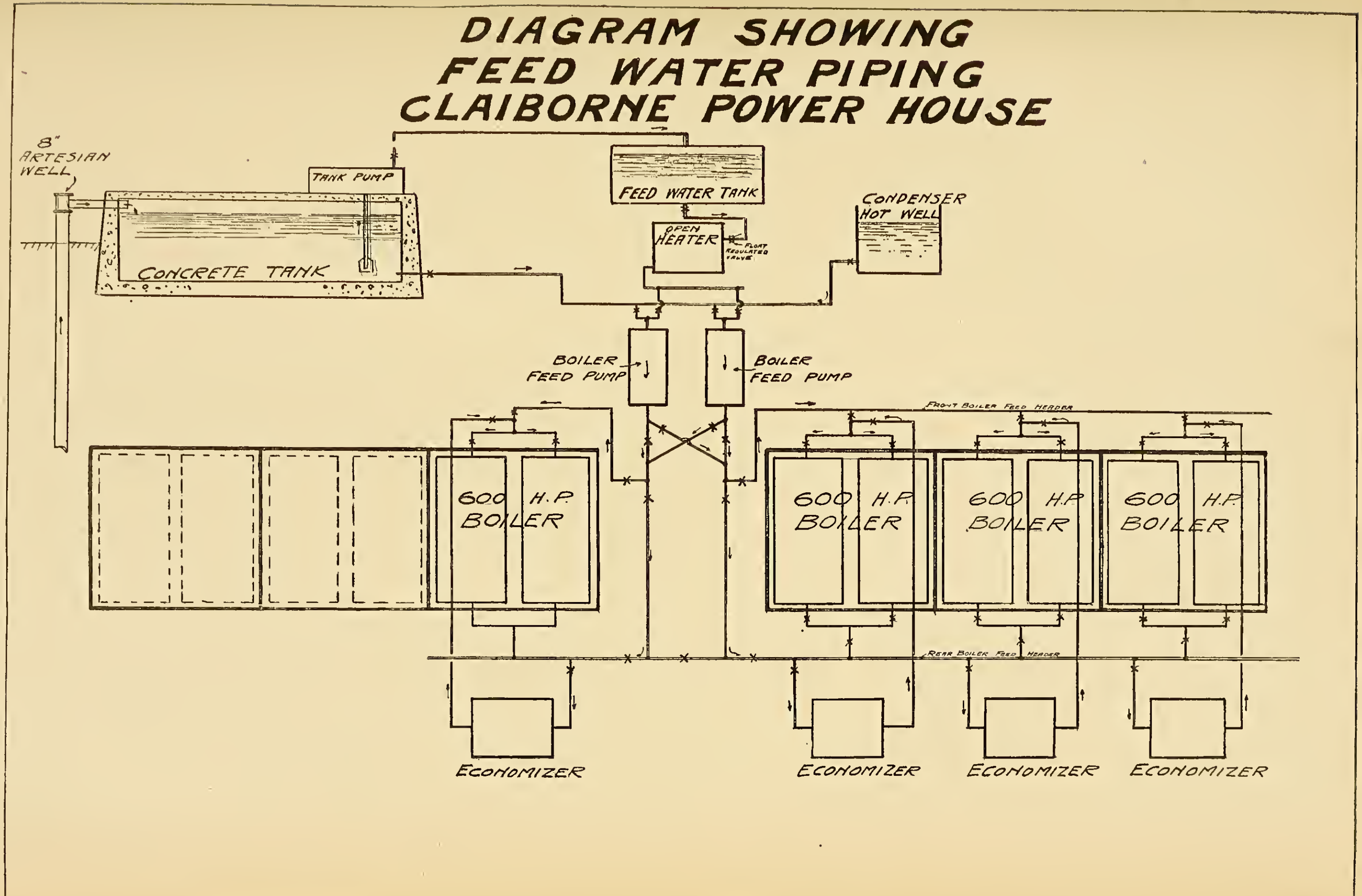


DIAGRAM SHOWING
FEED WATER PIPING
CLAIBORNE POWER HOUSE
8" ARTESIAN WELL
TANK PUMP
CONCRETE TANK
FEED WATER TANK
OPEN HEATER
FLOAT REGULATED VALVE
CONDENSER HOT WELL
BOILER FEED PUMP
BOILER FEED PUMP
FRONT BOILER FEED HEADER
600 H.P. BOILER
600 H.P. BOILER
600 H.P. BOILER
600 H.P. BOILER
REAR BOILER FEED HEADER
ECONOMIZER
ECONOMIZER
ECONOMIZER
ECONOMIZER

Fig. 7.

at which the water will flow into the vacuum without pumping against the entire static head.

This system also requires the use of a dry vacuum pump which takes care of the air leakage and is well adapted to plants of this type, where a comparatively large number of engines are operated, as it obviates the necessity for operating a separate condenser for each engine and the pumps used are less complicated than the duplex or other types frequently used.

Type of Engines. — The station will be equipped as follows:

Two 1 200 kw. Filer & Stowell cross compound engines, two 800 kw. cross compound Allis engines, two 300 kw. tandem compound Allis engines, two 500 kw. General Electric motor generators. The engine units are all direct connected, the motor generators will be used to transform alternating current received from the main station to railway current at the Claiborne Station, or to transform railway current for delivery to the lighting system or to any of the other stations.

Switchboard and Electrical. — The switchboard is mounted on an elevated gallery arranged symmetrically along the front wall of the engine-room, the railway portion being on the right and the alternating portion on the left. This station, in addition to generating railway current, will act as a distributing station and will contain the transformers and switchboard apparatus requisite for the operation of about 700 arc lamps.

All of the alternating switches in this station are of the enclosed oil break type, mounted in concrete cells and controlled by means of pilot switches on the main switchboard.

The direct current or railway switchboard controls the positive side of the generator by means of hand-operated switches and circuit breakers, but the negative and the equalizer, which in this case is on the negative side, are controlled by means of electrically operated, remote control switches, the pilot switches for their operation being mounted on the generator panels. By this means a switchboard operator may quickly and positively control all of the switches at any one or all of the eight generators without leaving the platform.

Provision has been made for either underground or overhead transmission or both. At the present time the high tension cables come into the station underground and the railway and other distributing circuits pass out overhead.

Impeller. — A 36-in. centrifugal pump has been installed at the end of the intake pipe heretofore described, the function of which will be to take water out of the upper half of the pipe and

discharge into the lower half for the purpose of washing out any sediment which may accumulate. This pump has a capacity of 40 000 gal. per minute against an 8-ft. head and is to be operated by 300 h.p. motor. It is expected that this will only be required at intervals of a week or ten days and then only for probably an hour.

Baronne Street Station.

The Baronne Street Station, known as Edison No. 1, having a capacity of about 4 000 kw. direct current and of about 1 500 kw. alternating current capacity, has been built for some years, This station will not be discussed at any great length in this paper except to say that the station is tied to the central power station electrically by means of the high tension cables and will be tied to the sub-stations electrically both from the high tension alternating current side and on the low tension direct current side with every facility for receiving current from any of the other stations and for transmitting current to any of the other stations in the event it should at any time be necessary.

This station was recently equipped with twelve 300-h.p. Murphy furnaces set in batteries of three stokers to two boilers. This proved to be a very difficult and unusual job owing to the fact that the requisite stoker capacity could not be installed under the single units. Therefore it was found expedient to install three stokers under two boilers, which necessitated supporting a portion of the center wall from the boiler girders. This installation has now been in operation over a year and has proven very satisfactory from the standpoint of efficiency, capacity, smoke abatement and economy.

Valence Sub-Station.

The Valence Sub-Station is located at the corner of Valence and Franklin streets. The ultimate installation will probably be 5 000 or 6 000 kw., but at present the equipment consists of constant current transformers and switchboard for supplying 660 arc lamps and two 500-kw. motor generator sets for the supply of railway current. This station is designed to receive 6 600-volt alternating current from the central station or from any other station via the central station and it is here transformed to railway current or any other kind of current required to meet the demand at that point.

This station presents a fair example of modern sub-station design and construction.

Algiers.

The Algiers Sub-Station, although owned and operated by other parties, receives its energy in the shape of high tension alternating current from any of the generating stations of the New Orleans Railway & Light Co., but ordinarily will receive its supply from the central station. The current delivered at the Algiers Station is used for commercial lighting, power and arc lighting and for the operation of an electric car system.

Duplicate transmission lines have been provided, the principal feature of these being the submarine cables crossing the river at Market Street and at Louisa Street. These are 00–three conductor stranded cables, insulated with rubber and protected by galvanized iron wire armor. These cables terminate in suitable cable houses located on each side of the river at the points designated, and are anchored at each shore anchorage and at three points in the river bed.

In addition to the stations referred to above there are two Edison sub-stations built within the underground district, one of which is now temporarily operating on Magazine Street near Poydras. The other is being built on Bourbon Street near the down-town load center. There is also the St. Charles power house containing 1 100 kw. of generating apparatus, the operation of which may shortly be discontinued except on special occasions; and the Napoleon Avenue power house, which has, with the exception of a few days, been out of commission for the past two and a half years.

Underground Conduit.

In connection with the power station work there has been installed for the same company about 600 000 ft. of underground conduit, designed for electrical service, together with approximately 150 manholes. The design, furnishing and erection of about 500 ornamental iron arc lamp poles have also been completed.

The arc lamp poles are of special design, incorporating features requisite to meet the local conditions.

The conduit requirements in this city are somewhat out of the ordinary on account of the local conditions, and for this reason it was deemed expedient to adopt a special construction throughout. The system installed consists of fiber conduit surrounded by gravel concrete laid with 1 in. of concrete between ducts and approximately 4 in. on the outside of ducts, the whole being inclosed in cypress troughs or boxes.

The manholes are built of molded concrete blocks of a special design, combining the following features:

1. They are practically watertight.

2. They may be built more quickly than brick and are stronger and more sightly after they are built.

3. The design incorporates a shelf for the support of the cables, which also acts as a barrier and which serves to prevent electrical arcs being communicated from one cable to another in the manhole.

This type of manhole has been compared only with brick, owing to the impracticability of a monolithic construction of manholes on account of the variety of shapes desired and on account of the obstructions and inability to recover and use the forms repeatedly.

Arc Lamps.

The arc light system provided for the city lighting consists of approximately 3 000 series alternating enclosed arc lamps as called for by the specifications of the city. These possess some unusual features. It was found that the ordinary commercial arc lamp would not comply with the conditions set forth in the city specifications and an entirely new design of lamp had to be provided. This lamp is operated normally at 7.8 amperes instead of 7.5, and at 87 volts pressure instead of about 72, in the ordinary lamp.

DISCUSSION.

Q. By Mr. Lawes. — What is your idea as to the comparative merits of multi-phase and single-phase electric systems?

A. The single-phase current is ordinarily only suitable for light or for small motors, except that low-frequency alternating single-phase current is now being extensively used in interurban railway motors recently brought out by the different electrical companies. Single-phase railway motors are now being built of 25-cycle frequency, operating on either alternating or direct current. For that reason, in order to provide a system from which we can operate any kind of service, it is desirable to install either the two-phase or three-phase system, and the three-phase is the simplest and most commonly used. Any kind of electrical apparatus that has been so far offered may be operated from the three-phase system through the medium of transformers and converters.

Q. Reduced to single-phase?

A. No; to change the voltage or frequency. The single-phase system is only applicable to special railway motors and this type is used principally in interurban work where stops are infrequent.

Q. By Mr. Wood. — How do you remove silt from the intake pipes?

A. By means of the circulating pumps or impellers, the function of these being to propel the water from one pipe into the other. The pump in central station may operate in either direction and is intended to create a head of only 8 or 10 ft.

Q. At what time would you have to take it in opposite direction?

A. In case the strainers get stopped up, the direction of flow could be changed; this would tend to clean them.

Q. How is the impeller driven?

A. By means of a 700-h.p. motor.

Q. The plant will have to run non-condensing, of course, when you are cleaning out pipes?

A. Not necessarily. The impeller pump is designed to circulate twice as much water as the plant will consume, and while the temperature of the water will rise, it would still give a fair vacuum.

Q. Do you anticipate serious trouble from silting?

A. We have had an experience at the Claiborne Station. We had a pipe installed and it remained idle for something like five months and filled up absolutely solid for about 40 ft. in length. When we were ready to start we simply opened the valve and the flow commenced. I am not nearly as apprehensive about these things as I was. There is sure to be a certain amount of deposit in such pipes, but it is only a question of getting up a sufficient circulation to get it out. We figure that if the silt was carried in at a certain velocity, it would certainly require more than that to get it out. That is what the impellers have been provided for.

Q. Will that water be flowing at all times — will it not be stationary at times?

A. There will always be some water going through. We figure that the present demands do not call for more than one half of the area of one of these pipes. The flow will therefore be very slow and the pipes will probably silt up to a certain point, but there is not a particle of danger of an entire stoppage.

Q. What were the features influencing the selection of steel stacks?

A. Better looking, stronger, occupy less space and cheaper, taking into consideration cost of foundations.

Q. Is there much danger of stack getting out of plumb in this country?

A. Here in New Orleans I should say not. One consideration that has favored the building of steel stacks has been their ability to resist high wind velocities.

Q. Are your steel stacks lined?

A. They are lined to the roof line only.

Q. Don't you consider the fact that a steel stack has to be painted very often quite a drawback?

A. That was taken into consideration. Painting does not prove to be a serious factor, requiring on an average painting a stack about every two years, and the cost of painting is very slight.

Q. What is the life of a steel stack?

A. I do not think anybody has found out. I do not know of any large steel stack that has been used continuously that has deteriorated, except around the ornamental hood. If a steel stack is used continuously I don't think there will be any corrosion inside, and if it is painted when it needs it, I don't think there will be much on the outside. If steel stacks are in use only intermittently they will deteriorate very rapidly near the top.

Q. Are these stacks all calked?

A. None of them are calked.

Q. Which way do you let your joint lap?

A. The laps are made so that the water will drain on the outside.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1907, for publication in a subsequent number of the JOURNAL.]

REPORT OF THE SPECIAL COMMITTEE ON REINFORCED CONCRETE OF THE ENGINEERS' CLUB OF ST. LOUIS EMBODIED IN THE BUILDING ORDINANCES OF THE CITY OF ST. LOUIS.

Specifications for Reinforced Concrete Structures.

[Discussed by members of the Club, May 17, 1907.]

Definitions.

Reinforced Concrete 1. Reinforced concrete is a concrete in which steel is embodied in such manner that the two act in unison in resisting stresses due to external loading.

Concrete 2. Concrete is an artificial stone resulting from a mixture of Portland cement, water and an aggregate.

Portland Cement 3. Portland cement shall be as defined in the Standard Specifications, adopted on June 14, 1904, by the American Society for Testing Materials.

Aggregates 4. An aggregate, as herein used, means one or more of the following materials: sand, broken stone, gravel, hard burned clay. Aggregates will be divided into two classes, fine aggregates and coarse aggregates. A fine aggregate will include all aggregate passing a No. 8 sieve. A coarse aggregate will include all aggregate passing a 1-in. ring and retained on a No. 8 sieve.

Quality of Materials.

Portland Cement 5. Portland cement shall conform to the requirements of the specifications of the American Society for Testing Materials, as adopted June 14, 1904, with all subsequent amendments thereto.

Grading of Aggregates 6. Aggregates — fine aggregates shall be well graded in size from the finest to at least the size retained on a No. 10 sieve. Coarse aggregates shall also be well graded in size from the finest to at least the size retained by a $\frac{9}{16}$-in. ring. Fine aggregates may contain not more than 5 per cent., by weight, of clay, but no other impurities. Coarse aggregates shall contain no impurities.

Sand 7. Sand shall be equal in quality to the Mississippi River sand.

Broken Stone 8. Broken stone shall be either limestone, chatts, or granite, or some other stone equal to one of these in the opinion of the Commissioner of Public Buildings.

9. Hard burned clay shall be made from suitable clay free from sand or silt, burned hard and thoroughly. Absorption of water should not exceed 15 per cent. **Hard Burned Clay**

10. *Concrete.* — The solid ingredients of the concrete shall be mixed by volume in one of the following proportions: **Proportion of Concrete**

(*a*) Not more than three parts fine aggregate to one of cement.

(*b*) Not more than two parts of fine aggregate and four parts of coarse aggregate to one of cement, but in all cases the fine aggregate shall be 50 per cent. of the coarse aggregate.

11. Concrete shall have an ultimate strength in compression in 28 days of not less than the following: **Strength of Concrete**

Burned clay concrete — 1 000 lb. per square inch.

All other concrete — 2 000 lb. per square inch.

12. Steel shall be medium steel or high elastic limit steel. The physical properties shall conform to the following limits: **Physical Properties of Steel**

	Medium Steel.	High Elastic Limit Steel.
Elastic limit,	Not less than 30 000.	Not less than 50 000.
Percentage of elongation, min. in 8 in.,	$E = \frac{1\,800\,000}{f - 10\,000} - 10.$	$E = \frac{1\,800\,000}{f - 10\,000} - 10.$
Cold bend without fracture on outer circumference,	180 degrees flat.	90 degrees to radius = 5 times thickness.
Character of fracture,	Silky.	Silky or fine granular.

f = unit stress in steel at ruptures.

13. Tests shall be made on specimens taken from the finished bar, and certified copies of test reports shall be furnished the Commissioner of Public Buildings at his request. **Test Specimens of Steel**

14. Bending tests shall be made by pressure. **Bending Tests**

15. Finished material shall be free from seams, flaws, cracks, defective edges or other defects, and have a smooth, uniform and workmanlike finish, and shall be free from irregularities of all kinds. **Finished Steel**

16. The net area of cross-section of finished steel members shall not be less than 95 per cent. of the area shown in the approved design. **Minimum Finished Section**

Execution.

17. All reinforced concrete work shall be built in accordance with approved detailed working drawings. These drawings shall be submitted to the Commissioner of Public Buildings for ap- **Drawings**

proval, and no work shall be commenced until the drawings shall have been approved by him.

Condition of Surface of Steel

18. The steel used for reinforcing concrete shall have no paint upon it, but shall present only a clean or slightly rusted surface to the concrete. All dirt, mud and other foreign matter shall be removed.

Cleaning Steel

19. If the steel has more than a thin film of rust upon its surface it shall be cleaned before placing in the work.

Unit Measure of Cement

20. In proportioning materials for concrete, one bag containing not less than 93 lb. of cement shall be considered 1 cubic foot.

Mixing Concrete

21. The ingredients of the concrete shall be so thoroughly mixed that the cement shall be uniformly distributed throughout the mass and that the resulting concrete will be homogeneous.

Wetness and Placing of Concrete

22. The concrete shall be mixed as wet as possible without causing a separation of the cement from the mixture, and shall be deposited in the work in such manner as not to cause the separation of mortar from coarse aggregate.

Placing Concrete

23. Concrete shall be placed in the forms as soon as practicable after mixing, and in no case shall concrete be used if more than 1 hr. has elapsed since the addition of its water. It shall be deposited in horizontal layers not exceeding 8 in. in thickness and thoroughly tamped with tampers of such form and material as the circumstances require.

Placing Steel

24. The steel shall be accurately placed in the forms and secured against disturbance while the concrete is being placed and tamped, and every precaution shall be taken to insure that the steel occupies exactly the position in the finished work as shown on the drawing.

Location of Joints

25. Before the placing of concrete is suspended the joint to be formed shall be in such place and shall be made in such manner as will not injure the strength of the completed structure.

Joining Old and New Work

26. Whenever fresh concrete joins concrete that has set, the surface of the old concrete shall be roughened, cleaned and thoroughly slushed with a grout of neat cement and water.

Freezing Weather

27. No work shall be done in freezing weather, except when the influence of frost is entirely excluded.

Protection of Structural Parts

28. Until sufficient hardening of the concrete has occurred, the structural parts shall be protected against the effects of freezing, as well as against vibrations and loads.

Protection of Concrete from Drying

29. When the concrete is exposed to a hot or dry atmosphere special precautions shall be taken to prevent premature drying by keeping it moist for a period of at least 24 hours after it has

taken its initial set. This shall be done by a covering of wet sand, cinders, burlap, or by continuous sprinkling, or by some other method equally effective in the opinion of the Commissioner of Public Buildings.

Removal of Forms during Warm Weather

30. If, during the hardening period, the temperature is continually above 70 degrees fahr., the side forms of concrete beams and the forms of floor slabs up to spans of 8 ft. shall not be removed before four days; the remaining forms and supports not before ten days from the completion of tamping.

Removal of Forms during Cold Weather

31. If, during the hardening period, the temperature falls below 70 degrees fahr., the side forms of concrete beams and the forms of floor slabs up to spans of 8 ft. shall not be removed before seven days; the remaining forms and the supports not before fourteen days from the completion of the tamping. But if, during the hardening period, the temperature falls below 35 degrees fahr., the time for hardening shall be extended by the time during which the temperature was below 35 degrees fahr.

Forms

32. Forms for concrete shall be sufficiently substantial to preserve their accurate shape until the concrete has set, and shall be sufficiently tight so as not to permit any part of the concrete to leak out through cracks or holes.

Cleaning Forms

33. Before placing the concrete, the inside of the forms shall be thoroughly cleaned of all dirt and rubbish, the forms of all beams, girders and columns being constructed with a temporary opening in the bottom for this purpose.

Loading Tests

34. If loading tests are considered necessary by the Commissioner of Public Buildings, they shall be made in accordance with his instructions, but the stresses induced in all parts of a structural member by its test load shall be the same as if the member were subjected to twice the dead load plus twice the assumed load.

Tests of Materials

35. All tests of material herein required shall be made by testing laboratories of recognized standing, and certified copies of such test reports shall be filed with the Commissioner of Public Buildings.

Design.

Weight of Burned Clay Concrete

36. The weight of burned clay concrete, including the steel reinforcement, shall be taken at 120 lb. per cubic foot.

Weight of Other Concrete

37. The weight of all other concrete, including the reinforcement, shall be taken at 150 lb. per cubic foot.

Weights of Materials

38. Besides the above, in calculating the dead loads, the weights of the different materials shall be assumed as given in Table No. I.

TABLE No. I.

WEIGHTS OF BUILDING MATERIALS, ETC., IN POUNDS PER CUBIC FOOT.

Material.	Weight.	Material.	Weight.
Paving brick	150	Plaster	140
Building brick	120	Glass	160
Granite	170	Snow	40
Marble	170	Spruce	25
Limestone	160	Hemlock	25
Sandstone	145	White pine	25
Slag	140	Oregon fir	30
Gravel	120	Yellow pine	40
Slate	175	Oak	50
Sand, clay and earth	110	Cast iron	450
Mortar	100	Wrought iron	480
Stone concrete	150	Steel	490
Cinder concrete	90	Paving asphaltum	100

Live Loads

39. The following table gives the uniformly distributed live loads for which structural members shall be designed when their dead loads are as given in the first column, A:

TABLE No. II.

DEAD LOAD. POUNDS PER SQUARE FOOT. (Column A.)	CORRESPONDING LIVE LOAD. POUNDS PER SQUARE FOOT. (1)	(2)	(3)	(4)
40 or under	72	103	155	194
50	63	93	140	175
60	59	84	126	158
70	53	76	114	143
80	48	69	104	130
90	46	64	96	120
100	41	58	87	109
110	37	53	80	100
120	34	49	74	93
130	31	44	66	81
140	29	41	62	78
150 or over	27	39	59	74

Dwellings, Etc.

40. The live loads on floors for dwellings, apartment houses, dormitories, hospitals and hotels shall be as given in column 1 of Table No. II.

Schoolrooms, Etc.

41. For schoolrooms, churches, offices, theater galleries, use column 2, Table No. II.

Stores, Etc.

42. For ground floors of office buildings, corridors and stairs in public buildings, ordinary stores, light manufacturing establishments, stables and garages, use column 3, Table No. II.

Assembly Rooms, Etc.

43. For assembly rooms, main floors of theaters, ball-rooms,

gymnasiums or any room likely to be used for dancing or drilling, use column 4, Table No. II.

44. For sidewalks, 300 lb. per square foot. **Sidewalks**

45. For warehouses, factories, special according to service, but not less than column 4 of Table No. II. **Warehouses, Etc.**

46. For columns the specified uniform live loads per square foot shall be used with a minimum of 20 000 lb. per column. **Columns**

47. For columns carrying more than five floors the live loads may be reduced as follows: **Reduction on Columns**

For columns supporting the roof and top floor, no reduction.

For columns supporting each succeeding floor, a reduction of 5 per cent. of the total live load may be made until 50 per cent. is reached, which reduced load shall be used for the columns supporting all remaining floors.

48. This reduction is not to apply to live load on columns of warehouses and similar buildings which are likely to be fully loaded on all floors at the same time. **Exceptions to Reduction on Columns**

49. The method used in computing the stresses shall be such that the resultant unit stresses shall not exceed the prescribed unit stresses as computed on the following assumptions: **Theory of Stresses**

(1) That a plane section normal to the neutral axis remains such during flexure, from which it follows that the deformation in any fiber is directly proportionate to the distance of that fiber from the neutral axis.

(2) That the modulus of elasticity remains constant within the limits of the working stresses fixed in these regulations and is as follows:

Steel, 30 000 000 lb. per square inch.
Burnt clay concrete, 1 500 000 lb. per square inch.
All other concrete, 2 000 000 lb. per square inch.

(3) That concrete does not take tension, except that in floor slabs, secondary tension induced by internal shearing stresses may be assumed to exist.

Unit Stresses.

50. The allowable unit stresses under a working load shall not exceed the following: **Unit Working Stresses**

Burned clay concrete:
Direct compression, 300 lb. per square inch.
Cross bending, 400 lb. per square inch.
Direct shearing, 150 lb. per square inch.
Shearing where secondary tension is allowed, 15 lb. per square inch.

All other concretes:

Direct compression, 500 lb. per square inch.

Cross bending, 800 lb. per square inch.

Direct shearing, 300 lb. per square inch.

Shearing where secondary tension is allowed, 25 lb. per square inch.

STEEL.

	Medium Steel.	High Elastic Limit Steel.
Tension	14 000	20 000

Compression in Steel

51. The compression in the steel shall be computed from the corresponding compression in the concrete, except for hooped columns.

Bonding Stress—Plain Bars

52. The bonding stress between steel and concrete under working load shall not exceed the following for plain steel:

For medium steel, 50 lb. per superficial square inch of contact.

For high elastic limit steel, 30 lb. per superficial square inch of contact.

Bonding Stress Other than Plain Bars

53. For bars of such shape throughout their length that their efficiency of bond does not depend upon the adhesion of concrete to steel, the allowable bonding stress under working load shall be determined as follows:

The bars shall be imbedded not less than 6 in. in concrete as herein defined, and the force required to pull out the bar shall be ascertained. At least five such tests shall be made for each size of bar and an affidavit report of the test shall be submitted to the Commissioner of Public Buildings, who shall then fix one fourth of the average stress thus ascertained at failure as the allowable working stress.

Maximum Column Length

54. The unsupported length of a column shall not exceed fifteen times its least lateral dimension.

Combined Flexure and Compression

55. In a column subjected to combined direct compression and flexure, the extreme fiber stress resulting from the combined actions shall not exceed the unit stress prescribed for direct compression.

Reinforcement in Columns

56. All columns shall have longitudinal steel members so arranged as to make the column capable of resisting flexure. These longitudinal members shall be stayed against buckling at points whose distance apart does not exceed twenty times the least lateral dimension of the longitudinal member. In no case shall the combined area of cross-section of these longitudinal members be less than 1 per cent. of the area of the concrete used

in proportioning the column, and the stays shall have a minimum cross-section of three one-hundredths of a square inch (0.03 sq. in.)

57. If a concrete column is hooped with steel near its outer surface either in the shape of circular hoops or of a helical cylinder, and if the minimum distance apart of the hoops or the pitch of the helix does not exceed one tenth the diameter of the column, then the strength of such a column may be assumed to be the sum of the following three elements: **Hooped Columns**

(1) The compressive resistance of the concrete when stressed not to exceed 500 lb. per square inch for the concrete inclosed by the hooping, the remainder being neglected.

(2) The compressive resistance of the longitudinal steel reinforcement when stress does not exceed allowable working stress for steel in tension.

(3) The compressive resistance which would have been produced by imaginary longitudinals stressed the same as the actual longitudinals; the volume of the imaginary longitudinals being taken at two and four-tenths (2.4) times the volume of the hooping. In computing the volume of the hooping it shall be assumed that the section of the hooping throughout is the same as its least section. If the hooping is spliced the splice shall develop the full strength of the least section of the hooping.

58. The minimum covering of concrete over any portion of the reinforcing steel shall be as follows: **Minimum Covering of Steel**

For flat slabs, not less than one inch.

For beams, girders, ribs, etc., not less than 1.5 in.

For columns, not less than 2 in. In computing the strength of columns, other than hooped columns, the outside one inch around the entire column shall be neglected.

59. For flat slabs continuous over two or more supports and uniformly loaded, the bending moment may be taken as $\frac{WL}{12}$ in which W equals total load on the span and L the center to center distance between supports. **Continuous Slabs**

60. Beams continuous over supports shall be reinforced to take the full negative bending moment over the supports, but shall be computed as non-continuous beams. **Continuous Beams**

61. The minimum distance center to center of reinforcing steel members shall not be less than the maximum diameter or diagonal dimensions of cross-section plus 2 inches. **Minimum Spacing of Steel**

62. In designing T-beams, the width of floor slab which may be assumed to act as compression flange of the beam shall not **T-Beams**

Splicing Steel exceed one fourth of the span of the beam, but in no case shall it exceed the distance, center to center, of beams.

63. If it is necessary to splice steel reinforcing members, either in compression or tension, the splice shall be either a steel splice that in tension will develop the full strength of the member, or else the members shall be lapped in the concrete for a length equal to at least the following: For plain bars of medium steel, forty times the diameter or maximum diagonal of cross-section. For plain bars of high elastic limit steel, seventy times the diameter or maximum diagonal of cross-section. For other than plain bars, the length of lap shall be in inverse ratio to the ratio of the allowed bonding stresses as herein required. In no case, however, shall the steel reinforcement in a beam or girder be lap spliced.

DISCUSSION.

Mr. Charles K. Traber (*by letter*). — I should like to say a few words regarding one of the definitions:

Paragraph 8 states, "Broken stone shall be either limestone, chatts, or granite, or some other stone equal to one of these in the opinion of the Commissioner of Public Buildings."

Being located in the "lead belt" of St. Francis County, only 65 miles from St. Louis, from which section all the chatts which would be used in St. Louis would necessarily come, I can give a little information concerning the properties of these "chatts." The material which forms the gangue in which the lead sulphide occurs is a very soft limestone, which disintegrates rather rapidly when exposed to the elements. The tailings from the concentrating mills, composed entirely of this limestone, are what are commonly known as "chatts." This district produces perhaps a hundred cars daily of these chatts, and with the exception of a small fraction taken by the railroads for ballast, it is all thrown on the dump.

All the larger mills now crush their ore to pass through a screen with 6 mm., or less than 0.25 inch openings. The greater part of the chatts is, however, very much finer than this. Probably 90 per cent. would pass through a No. 8 sieve. I have made some tests of this material and have found that the percentage of voids is about the same as for ordinary unscreened river sand. The chatts absorb a great deal of water, however, as a considerable proportion is in the form of a fine powder.

Chatts have been used extensively in this vicinity for the foundations of houses. For this purpose they are usually mixed in the proportion of 1 to 4. This makes a fairly good concrete,

but is not economical and is used only because the chatts are at hand and cost nothing. We have found that it is much more economical to crush rock for the coarse aggregate and to use chatts for the fine, as a substitute for sand. We are now placing some very heavy foundations for mill machinery and engines, and are using a mixture of one part cement, two parts chatts and four parts broken stone, which makes a very good concrete for this purpose. We are also putting in some reinforced floors, to carry concentrating tables, and after careful consideration have decided to use sand as the fine, and broken stone as the coarse, aggregate, although the sand must be brought from some distance at considerable expense.

Chatts can hardly be classified as either coarse or fine aggregate, and should not, I think, be included in paragraph 8. It should not, in my opinion, be used at all in reinforced work.

Mr. C. D. Purdon. — The writer hesitates to discuss a specification which has already become a law by being incorporated in the building ordinances. As discussion has been invited, he offers the following remarks:

In the definitions he suggests placing the second clause first, first defining concrete and next reinforced concrete.

In clause 4 the word "aggregate" occurs too often; he would suggest that it read, "Aggregate, as herein used, shall mean one or more of the following materials: sand, broken stone, gravel, hard burned clay. Aggregates shall be divided into two classes, fine and coarse. Fine aggregate will include all material passing through a No. 8 sieve, coarse all passing through a 1-in. ring and retained on a No. 8 sieve."

Section 6, third line, transpose the words "shall" and "also" so as to read, "Coarse aggregates also shall be well graded, etc."

Section 7. Add the words "as used in St. Louis."

Section 8. The word "chatts" is indefinite. The tailings from the lead mines at Joplin are excellent, those from Galena (Kan.) contain a good deal of clay, but those from the district immediately south of St. Louis are very different, and the writer doubts very much that they would make good concrete; all of the above are called "chatts."

Section 9. He suggests that samples of the hard burned clay be submitted to the Commissioner of Public Buildings for approval.

Section 12. Add the words "pounds per square inch" to the elastic limit.

Section 15. It does not seem necessary to insist upon a smooth finish for the steel, as a great part of its value is the bond it makes with the concrete.

Section 16 is vague. Section 17 provides that the work must be built in accordance with approved drawings, and 16 seems to set this provision aside; he would suggest that 16 read "not less than 95 per cent. of the area required by calculation."

Section 17. He would suggest that it read, "All reinforced concrete work shall be built in accordance with detail working drawings which have been approved by the Commissioner of Public Buildings."

Section 18. Omit "the" in first line, and "shall" and "only" in second line.

Section 21. Shorten so as to read, "The ingredients of the concrete shall be so thoroughly mixed that the resulting mass will be homogeneous."

Section 22. Omit the word "shall" in second line.

Section 23. Omit the words "shall concrete" in second line.

Section 24. He suggests that it read, "Steel shall be accurately placed in the form and secured against disturbance during the placing and tamping of the concrete; every precaution must be taken to insure its occupying in the finished work the position shown in the drawing."

Sections 25 and 26 might be consolidated and read, "When necessary to suspend the placing of concrete, the surface shall be left in such condition as to form a joint which will not impair the strength of the completed structure, and on resuming work this surface shall be made rough, cleaned and thoroughly slushed with a grout of neat cement."

Section 27. He suggests that it read, "No concrete shall be placed in freezing weather unless it be protected from the effect of frost."

Section 29. He suggests that it read, "When concrete is exposed to a hot or dry atmosphere special precautions shall be taken to keep it moist for at least 24 hours after initial set has occurred, by a covering of wet sand," etc.

Sections 30 and 31 might be consolidated and read, "If the temperature remains above 70 degrees fahr., the side forms of beams and the forms of floor slabs up to spans of 8 ft. shall remain in place four days after initial set has occurred, the remaining forms and supports, ten days. Should the temperature fall below 70 degrees fahr., these periods shall be respectively

seven and fourteen days; and should it fall below 35 degrees fahr., these last periods shall be extended an amount equal to the time during which the temperature remained below 35 degrees fahr."

Section 32. He suggests that it read, "Forms shall be substantial enough to preserve accurate shape until the concrete has set, and sufficiently tight to prevent any part of the concrete leaking out."

Section 33. He suggests it read, "All forms shall be constructed in such a manner as to allow of their being thoroughly cleaned, which must be done before any concrete is placed in them."

Section 34. He suggests it read, "Should the Commissioner of Public Buildings require loading tests to be made, they shall be made under his instructions and in such a manner as to produce stresses double those for which the member was designed."

Section 39, the writer understands, is intended to vary the live load with the span of floor, making, in fact, an allowance for impact, as is done in bridges. It certainly is anything but clear to the writer, the first impression conveyed by it being that the stronger the floor is made the less load it will carry; while this section may produce the desired result, it seems a roundabout way of specifying it; it would be clearer to the writer were the live load varied with the length of span or area of floor.

Section 45. He suggests it read, "For warehouses and factories special loading according," etc.

Section 49, clause 3. Read, "except in floor slabs, when secondary," etc.

Section 50. Two of the unit stresses for burned clay concrete are made one half of these for "all other concretes"; why should not the direct compression follow the same ratio?

Section 53 should provide some limit of time before making the test.

Section 58. Omit either the word "minimum," in the first line, or the words "not less than," in the third, fourth and fifth lines.

Section 60. Insert "otherwise" after "shall" in the second line.

Section 61. Omit "minimum" in first line.

Section 62. Omit "which may be" at end of first line.

Mr. A. E. Lindau. — Eternal vigilance is the keynote to success in the execution of reinforced concrete structures. The physical properties of materials used in the construction can

and should be tested at intervals during the progress of the work, but the placing of the concrete and handling of the reinforcement are dependent entirely upon proper supervision and upon the skill of the workmen.

There can be no question of the fact that the erection of reinforced concrete work presents a very serious problem at the present time. Other building materials are the product of nature's workshop or highly skilled manufacturing establishments, while the strength of concrete is a function of that most variable quantity, skilled labor. In fact, we do not enjoy the advantages offered by skilled labor in other types of building work. There is not comparison beween a good carpenter and a concrete worker as far as knowledge of the strength and proper proportion of their respective materials is concerned.

The demand for skilled workmen in the manipulation of concrete material has been recognized in some of the larger cities, to the extent of organizing or unionizing the labor, but thus far the increase in wages has not been accompanied by a relative increase in the efficiency of the labor. Ordinarily, when concrete is to be placed, a gang of men is organized, some of them having no experience whatever; by patience and unceasing effort they may be made to understand what is required after a few days, but just about that time the concreting has caught up with the carpenters, the force must be "laid off," only to be reorganized later. Consequently the skill that might be developed on work of some magnitude is denied us, and the problem is invariably reduced to one of supervision.

Reinforced concrete engineers are painfully aware of the fact that bids on their designs are as likely to be awarded to contractors who have never attempted reinforced concrete work before as to those having years of experience. To the credit of such contractors, however, it must be said that frequently they arrange to have some competent man in charge; if so, well and and good, but the possible lack of proper supervision should be guarded against by securing and organizing a sufficient number of reliable and experienced inspectors, who would see to it that ordinances and specifications are carried out.

Testing.

The proposed ordinance provides amply for the tests of materials required in the construction, but leaves the matter of loading the actual structure to the discretion of the Building Commissioner. It would seem as though it were more important

to test the structure than the materials of which it is made. And the very fact that the work must be tested, pass examination, as it were, would exert a healthy influence on the individuals responsible for the construction. In addition, tests would check the plan examiner's work, and curb the tendency to "shave" the design, by firms interested in the sale of materials. In fact, the establishment by the city of a testing plant or station where various forms of construction could be tested to destruction would aid in clearing the atmosphere of much of the mystery with which so many systems are surrounded.

Unit Stresses.

The allowable unit stresses seem too high for both the high and low carbon steel, and many engineers would consider 800 lb. per square inch in the concrete too high, particularly in view of the fact that the average ultimate strength of 1: 2: 4 concrete reported by experimenters during the year has averaged below 2 000 lb. This, however, was concrete hand mixed; with machine mixing, better results can be obtained. In a series of tests arranged from samples of concrete being placed in the Butler Building, 7 by 7 by 7 in. cubes gave 2 310, 2 260 and 1 340 at thirty days, while for sixty days 2 900, 2 350, 3 000 were obtained, amply justifying 800 lb. for working load. But 14 000 and 20 000 in the steel would give a factor of safety of about 2.5 or 3 on the ultimate, depending upon the strength of the concrete.

In order to determine, if possible, from experiment, the relation between stress in the steel and concrete, as well as the carrying capacity of the beam at the specified unit stresses, the speaker examined Professor Talbot's bulletins on beams. The 1905 bulletin is devoted to beams reinforced with mild steel bars, and the 1904 series had several tests in which high elastic limit bars were used. The load at the deformation in the steel corresponding to 14 000 lb. and 20 000 lb. was noted, the position of the neutral axis taken from the record equating the total force in compression to the total force in tension, the maximum fiber stress in compression computed, on the basis of a straight line stress strain curve. The value K or $\frac{M}{bd^2}$ was also computed, and a most remarkable agreement was found between these quantities and similar ones as determined from assumptions laid down in the ordinance, especially in the case of the values K. But the load which produced 14 000 lb. was approximately half

$E_s \cdot 29{,}000{,}000$
COMPUTED "C" $= \frac{E_s}{by_1} \times 2$.

TABLE GIVING CO-RELATED STRESSES FROM EXPERIMENTS. 4-17-07

K_0 = COEFFICIENT AT ULTIMATE MOMENT $M_0 \div bd^2$

REFERENCE AND BREAKING LOAD	BEAM-DIMENSIONS & KIND OF CONCRETE	% OF REINFORCEMENT	d	M_0	K_0	STEEL DATA: LOAD. λ_s FACTOR	STEEL DATA: $S = \lambda_s \times E_s$	STEEL DATA: g	STEEL DATA: $E_s \cdot g \cdot \lambda_s \times E_s$	CONCRETE DATA: y_1 FROM EXPERIMENT	CONCRETE DATA: OBSERVED λ_c	CONCRETE DATA: COMPUTED "C"	"K" FROM ORDINANCE	"C" FROM ORDINANCE	$M_R = (d-z) \Sigma_s$	$K = M_R \div bd^2$
PLAIN ROUND BARS																
TALBOT · 1905 11,000#	#5 · SPAN · 12'-0" 8"×11" - d = 10" 1-3-6 CONCRETE LOAD · 1/3 POINTS	.98	10"		330 23 353	5000 ⇐ .00048 2.2	14,000	4 · 1/2" ϕ .184°	11,000	.45d = 4.5"		610	120	660	8.5 93500	117
TALBOT · 1905 11,000#	#11 · SPAN · 12'-0" 8"×11" - d = 10" 1·3·6 CONCRETE LOAD · 1/3 POINTS	.98	10"		330 23 353	4500 ⇐ .00048 2.45	14,000	4 1/2" ϕ .184°	11,000	.48d = 4.8		575	120	660	8.4 92500	116
TALBOT · 1905 8800#	#40 · SPAN · 12'-0" 8"×11" - d = 10" 1·3·6 CONCRETE LOAD · 1/3 POINTS.	.98	10"		264 23 287	4500 ⇐ 1.96	14,000	4 1/2" ϕ .184°	11,000	.5d = 5"		550	120	660	8.3 91500	114
TALBOT · 1905 14400#	#33 SPAN · 12'-0" 8"×11" - d = 10" 1-3-6 CONCRETE LOAD · 1/3 POINTS.	1.66	10"		432 23 455	8000 ⇐ 1.8	14,000	3 · 3/4" ϕ 1.32°	18,500	.5d = 5"		925	196	930	8.3 154000	192
TALBOT · 1905 12400#	#45 SPAN · 12'-0" 8"×11" - d = 10" 1-3-6 CONCRETE LOAD · 1/3 POINTS	1.84	10"		372 23 395	7800 ⇐ 1.59	14,000	3 - 1/2" ϕ 2 - 3/4" ϕ 1.46°	20,400	.6d = 6"		850	210	1000	8.0 163000	204
TALBOT · 1905 15200#	#46 SPAN · 12'-0" 8"×11" - d = 10" 1-3-6 CONCRETE LOAD · 1/3 POINTS	2.76	10"		456 23 479	10500 ⇐ 1.45	14,000	5 · 3/4" ϕ 2.2°	30,800	.68d = 6.8"		1130			7.8 240000	300
CORRUGATED BARS HIGH ELASTIC LIMIT										$K = .0162\,W + 27$.						
TALBOT · 1904 20900#	#20 SPAN · 14'-0" 12"×13 1/2" d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS	.70	12"		338 27 365	8800 ⇐ 2.36	20000	5 · 1/2" O.S. 1.0°	20,000	.42d = 5"		667	124	760	10.3 206000	119
TALBOT · 1904 20600#	#2 SPAN · 14'-0" 12"×13 1/2" d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS.	.70	12"		335 27 362	8500 2.40	20000	5 · 1/2" O.S. 1.0°	20,000	.4d = 4.8"		692	124	760	10.4 208000	120
TALBOT · 1904 29000#	#13 SPAN = 14'-0" 12 × 13 1/2" d = 12 1-3-6 CONCRETE LOAD - 1/3 POINTS	.97	12"		470 27 497	12800 2.26	20000	7 · 1/2" O.S. 1.4°	28000	.45d = 5.4"		865	168	925	10.2 285000	165
TALBOT · 1904 34300#	#28 SPAN · 14'-0" 12"×13 1/2" · d = 12" 1-3-6 CONCRETE LOAD - 1/3 POINTS.	1.52	12"		555 27 582	15400 2.23	20000	6 · 3/4" O.S. @ .565 2.19°	43,800	.52d = 6 1/4"		1170	260	1260	9.9 435000	252
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

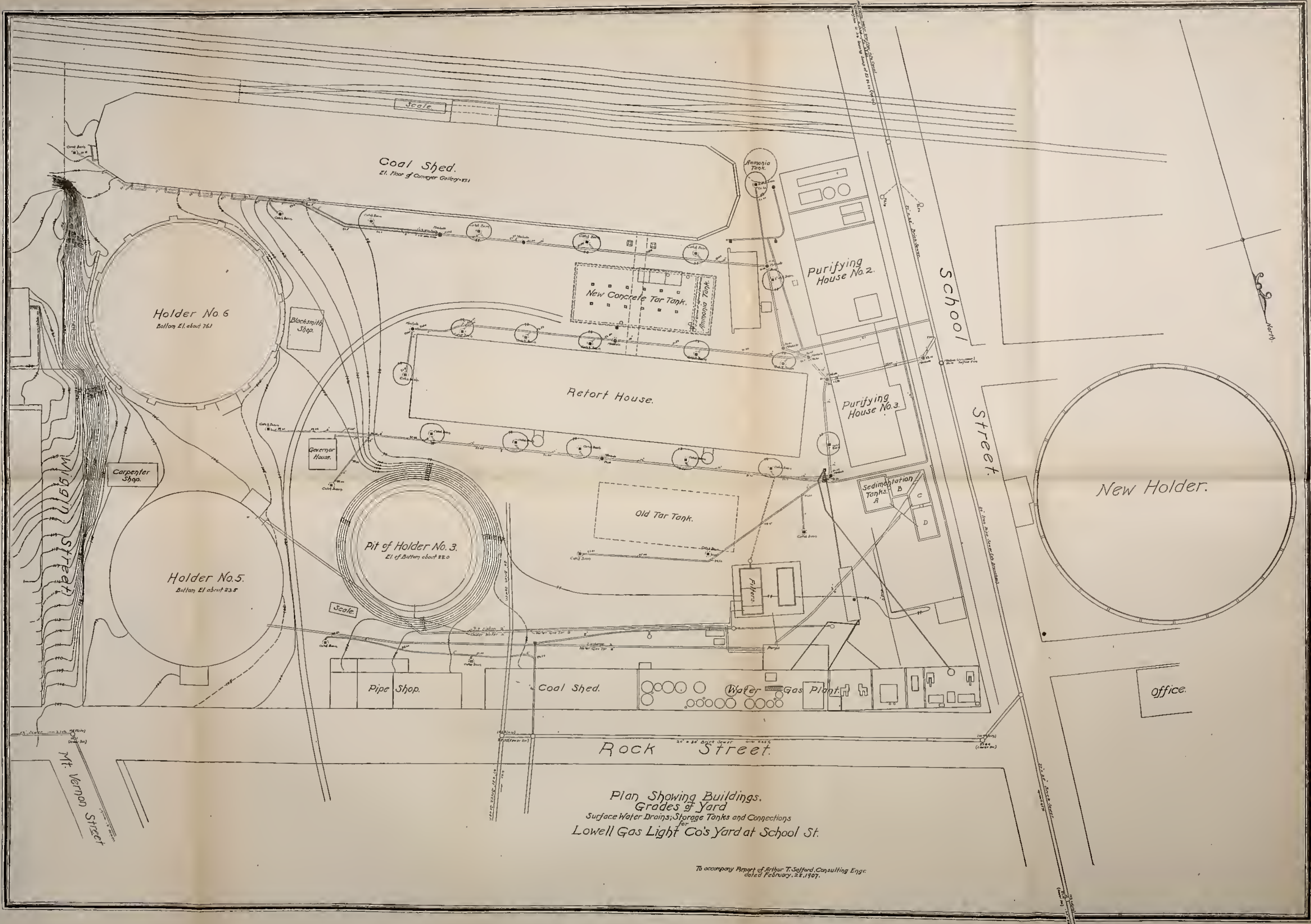
of the ultimate. This, however, is 1: 3: 6 concrete; with 1: 2: 4 concrete it is safe to say that these strength factors would increase until the working factor is about one third of the ultimate. (See Condron's paper before the Western Society of Engineers.)

Referring to table, column 7 gives the total live load on beam when the elongation, as noted, produced 14 000 lb. per square inch in the steel, noted in the next column. In other words, that load is noted which produces 14 000 lb. per square inch in beams reinforced with mild steel, and 20 000 lb. with high elastic limit steel. This load, then, compared with load at which failure took place, and the ratio called factor, is noted in the column with the load. The factor varies from 2.45 with 0.98 per cent. reinforcement to 1.45 at 2.76 per cent. Although it is quite natural that the factor decreases when the beam is over-reinforced, it is interesting to note that even with the 0.98 per cent. reinforcement the factor averaged little over 2. Comparing columns 13, marked "computed C," and 15, "C from ordinance," discloses the fact that the fiber stresses given by assumption in ordinance are higher than those computed from actual observation, which can be explained by the modulus of elasticity in the test specimens differing from the value given in the ordinance. The neutral axis is determined by the ratio of deformation in top and bottom chord, and is, therefore, largely influenced by the ratio of the moduli. The value K, however, is a function of the effective depth and chord stress, and as it can readily be shown, experimentally and analytically, that the variation in the effective depth, that is, the distance from center of tension to center of compression, must necessarily be small, the agreement between values computed from the tests and from specifications of ordinance agree very closely. Compare column 14, "K from ordinance," with last column, 17, "$K = \frac{M_R}{bd^2}$". That the same if not greater factor of safety can be obtained with high elastic limit bars, if bond is such as to prevent slipping until elastic limit is reached when 20 000 lb. per square inch is assumed in the steel, is made evident by the lower section of tests quoted also from Professor Talbot. Indeed, the factor has very little variation, and falls only slightly below 2.25, even for 1.52 per cent. The remarks concerning extreme fiber stress in concrete and factor K apply to this set of tests as well as to the previous one. It would seem, then, that unless there is a serious discrepancy between the actual stress in the reinforcement and the stress as determined by extensometer readings, 14 000 lb. and

20 000 lb. per square inch stress in the steel will mean a factor of safety varying between 2 and 2.5. The ordinance, however, makes these factors much larger by requiring the beams to be figured as non-continuous, but constructed continuous with full reinforcement over support. Also by specifying that slabs shall be designed by the formula $\frac{wl}{12}$. Just how much this increase may be, cannot be determined until enough reliable tests have been made to give true average results. The speaker, however, has tested within the last six months a half dozen full-sized floor panels that were designed on the basis of $\frac{wl}{16}$, and in nearly every case the breaking load exceeded the computed ultimate by 50 per cent. or more. Beams tested at the same time proportioned by the formula $\frac{w}{12}$, exceeded their computed value. The result is that although the stresses may seem high, rules for design increase the factor of safety in all slabs and beams except non-continuous, perhaps even a little beyond the average practice throughout the country.

The many points of excellence about the ordinance are too numerous to take up in detail. It is sufficient to note that its enforcement will bring order out of chaos.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1907, for publication in a subsequent number of the JOURNAL.]


Coal Shed.
El. Floor of Conveyor Gallery
Scale.
Ammonia Tank.
Purifying House No. 2.
New Concrete Tar Tank.
Ammonia Tank
Holder No. 6
Bottom El. about 76.1
Blacksmith Shop.
Retort House.
Purifying House No. 3.
School Street.
New Holder.
Governor House.
Carpenter Shop.
Sedimentation Tanks. A B C D
Old Tar Tank.
Pit of Holder No. 3.
El. of Bottom about 88.0
Holder No. 5.
Bottom El. about 83.5
Wiggin Street
Scale.
Filters
Pipe Shop.
Coal Shed.
Water Gas Plant.
Office.
Rock Street.
Mt. Vernon Street
North
Plan Showing Buildings,
Grades of Yard
Surface Water Drains; Storage Tanks and Connections
for
Lowell Gas Light Co's Yard at School St.
To accompany Report of Arthur T. Safford, Consulting Engr. dated February, 28, 1907.

WASTES FROM LOWELL GAS LIGHT COMPANY'S YARD.

By Arthur T. Safford, Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, March 6, 1907.]

The following is a paper upon the work done at the Lowell Gas Light Company's yard east of School Street, Lowell, Mass., in connection with the improvements in the drainage of the yard.

The Lowell Gas Light Company has, for more than fifty years, occupied about six acres of land east of School Street, Lowell, and bounded by School, Rock and Wiggin streets and the Boston & Maine Railroad; in addition to this the company, within the last four years, has built a gas holder of 3 000 000 cu. ft. capacity and a new purifying house upon their land west of School Street, but nothing has been necessary so far in the way of drainage on the west side of School Street, and this paper will consider only the old yard.

About two thirds of the old yard east of School Street previous to 1904 was below Elevation 98 on the Locks & Canals datum, which is 15 ft. above the ordinary running mark of the water in the Pawtucket Canal, about 300 ft. away across the Boston & Maine Railroad. The easterly third of this yard was most of it at Elevation 105 on the same datum, but the last 25 ft. is a rocky ledge rising rapidly to Elevation 125.

The low two thirds of the yard just previous to 1904 was occupied by a water gas plant, with a capacity of about 1 000 000 cu. ft. per day, and power plant, at the north side of the yard; a new concrete coal shed 475 ft. long by 70 ft. wide, occupying the south side; a new retort house 287 ft. by 62 ft., occupying the south-central part; a wooden tar tank 102 ft. by 41 ft., the north-central part and two old purifying houses the west side. In addition to these there were numerous small or abandoned buildings in other parts of this end of the yard.

On the area to the east of this were three gas holders, Nos. 3, 5 and 6, of the following size and capacity:

No. 3. 80 ft. in diameter; capacity...... 100 000 cu. ft. (approximate.)
No. 5. 125 ft. in diameter; capacity.................... 500 000 cu. ft.
No. 6. 130 ft. in diameter; capacity.................... 700 000 cu. ft.

In addition to these, and just south of No. 3 holder, there were in the ground the remains of the foundations of No. 4 holder pit which was about the size of No. 3.

I do not know with certainty the original material of the lowest parts of the yard, but it was evidently sand, hard pan and muck, overlying the ledge which was within about 10 ft. of the surface everywhere. All the different holders and foundations for buildings were built upon ledge, which had been blown out and removed at some time from most of the yard. There is every indication that the ledge had been shattered almost up to the base of the rocky hill at Wiggin Street.

The low places in the ground had been filled from time to time, but the material, mostly cinders and dirt, had been disturbed again and again on account of the numerous pipes which had been laid and relaid. The ground was full of blind drains, abandoned pipes of different sizes from 1 in. to 2 ft., and several subterranean springs and tar holes were discovered. In addition to this the old tar tank not only leaked but overflowed after storms and was the one place in the north side of the yard to catch all the drainage from rains or melting snow. From test holes dug in different parts of the yard (north of the new retort house) and elevations taken upon the water, it was estimated that there was at least 1 600 000 gal. of liquid of an objectionable character in the ground excluding what was more or less definitely contained by tanks and holders.

The city sewers around the property include a 30 by 20 in. oval brick sewer in Rock Street, with an average invert elevation of 87.91, connecting with a 30-in. iron pipe sewer with no branches in it, in School Street, to a point about half way down the west side of the yard; this in turn changing at a manhole to a 37 by 25 in. brick sewer, with an invert grade of 86.14 at the manhole opposite the west end of the yard. This sewer crosses the B. & M. Railroad tracks and turns down Western Avenue on the Gas Company's side of the canal, keeping the same size with a slope of 0.25 ft. per 100; continues down Western Avenue through Fletcher Street to Suffolk and through Suffolk towards the Merrimac River at Aiken Street. There is, however, an overflow for storm water into the Pawtucket Canal at School Street, with a crest 4 ft. long at Elevation 88.00, corresponding to the height of water in the sewer at this point when the sewer is about half full. This sewer in School Street takes the place of an older one which ran from Rock Street across the Gas Company's yard to Western Avenue.

The following is a comparison of the low places in the yard with the invert grade of the city sewer at a point where the drainage would naturally go.

	Height on Locks & Canals Datum.	Height Invert City Sewer, Same Datum.	Difference, Feet.
Holder No. 3. Bottom of pit, rough, approximate	89.5	88.38	+1.12
Holder No. 3. Approximate surface of water when full	109.	88.38	+20.62
Holder No. 5. Bottom of pit	83.5	88.38	—4.88
Holder No. 5. Approximate surface of water when full	105.	88.38	+16.62
Holder No. 6. Bottom of pit	76.1	88.38	—12.28
Holder No. 6. Approximate surface of water when full	105.	88.38	+16.62
Coal shed conveyor floor	87.1	86.14	+0.96
Old tar tank bottom, about	88.	86.14	+1.86
Old tar tank surface water, most of time	95.	86.14	+8.86

The pits of these different holders were originally full of water to seal the gas in the holders but had gradually become partially filled up with different liquids produced in the works in addition to the water. The capacity of these pits and the old tar tank is as follows:

No. 3 holder pit	829 100 gal. approximate.
No. 5 holder pit	2 021 500 gal. approximate.
No. 6 holder pit	2 953 900 gal. approximate.
Old tar tank	239 400 gal. approximate.
	6 043 900 gal. approximate.

Nos. 5 and 6 holders contain some objectionable matters which have been held there and the pits have overflowed once or twice, putting some weak ammoniacal liquor down into the lower yard; but the pits do not leak, and as far as I know there is no evidence that they ever contributed to the serious troubles which were the occasion for these changes. They were, therefore, left out of the general plan of improvements. No. 3, however, has had a bad record for many years, and the contents were continually leaking into the ground with a head of 20 ft. or less above the city sewers.

With particular reference to those liquids which required getting rid of: The ground below this holder was full of water

and liquors which filled up the interstices of the soil and loose filling, and, as already mentioned, there were about 1 600 000 gal. of objectionable liquids in the ground here, the 829 100 gal. in No. 3 holder and the 239 400 gal. in the old tar tank, a total of about 2 668 500 gal. to be taken care of. These amounts varied to some extent with the season of the year and the height of the ground water.

In addition to the coal and water gas products stored in the different tanks and ground, there were certain liquids of different sorts produced every day, in amounts which varied with the amount and kind of gas produced. At the time of my first report to the Gas Company, August 22, 1904, they were as follows:

Quantity passing filters, mostly water gas, tar and oil	11 000 to 20 000 gal. per day
Blow-off from gas engine	10 000 gal. per day
Ammoniacal liquor	1 000 gal. per day
Ground water pumped from coal shed	4 000 gal. per day
Coal tar	400 gal. per day
Maximum	35 400 gal. per day

Of this total, the 10 000 gal. per day blown off from the gas engine was not considered because the gas engine was taken out to give place to a steam engine; the ammoniacal liquor and tar could be sold if stored and kept separate from other liquids, and the ground water from the coal shed could be gotten rid of by draining the territory around the shed. There remained, then, this daily quantity of 11 000 to 20 000 gal. of water-gas refuse to be taken care of, besides that remaining in No. 3 holder and the ground.

I have no definite knowledge when the trouble from odors and gases in the city sewers began, but it is an old subject in Lowell, and the new city sewer around the company's yard was built at great expense just previous to the last serious trouble from these wastes. The following extracts from the Lowell *Sun* and *Courier-Citizen*, which are characteristic of a good many such articles appearing about this time, will give some idea of the effects produced and the various criticisms and remedies suggested. I will count on your discounting something from these statements to allow for personal feelings. In some cases statements have been left out of these clippings where personalities have been indulged in.

"JANUARY 14, 1903.

"The public hearing into the cause of gas in the cellars of houses in the vicinity of Suffolk Street was held in the room of the Board of Health yesterday afternoon, and before the board the remonstrants told their experiences with the overpowering odors which, from time to time, fill their houses. Although Mr. O—— was present, he was heard from very little, merely seconding motions on one or two occasions.

"Mr. J—— was the first man to be heard. He said he was an employee of Curley's Market, corner of Adams and Salem streets, and that on several occasions during the past year he had noted the awful odor which had caused so much trouble in the houses in the vicinity. Three or four weeks ago the smell lasted for 48 hr. at a stretch. He had heard many complaints from residents of the section. Not long ago, he said, the Catholic Young Men's League of St. Patrick's parish gave an entertainment and the odor was so strong that it was easily detected in the topmost floor of the building. He thought it was sewer gas and not inflammable.

"Mr. W——, living at 27 Cross Street, has noticed the smell for the past five years. It had, he said, made his mother so sick that she was unable to appear at the hearing being held. He couldn't eat his meals at times, the odor affecting his stomach. He said he didn't dare go into the cellar with a lighted lamp when the gas was the strongest. The tenants of his three-tenement block had moved out from time to time, and those who occupied the block at the present time were unceasing in their complaints. Butter and various other eatables placed in the lower part of the house were spoiled. He claimed the gas came into the cellar under the foundations of the house.

"Mr. R——, who owns eleven tenements on Broadway, represented his father at the hearing, and said that at times the smell was so offensive that it permeated the entire house from cellar to attic. He said that there was no gas piping in any of the houses. He hadn't noticed the odor for three weeks.

"Mrs. L——, 23 Cross Street, said that she, her sister and her daughter had been ill as a result of the gas in her home. She also said that a tenant of the house claimed that the death of an infant child was due to the presence of the fetid gas. She had called on the Board of Health to remove three barrels of apples, vegetables, butter and mincemeat which had spoiled as the result of the gas. Her dog had been found in such a bad condition that she had notified Agent Richardson of the Humane Society to kill it. In describing the effect of the gas on herself she said that it produced nausea, headache and finally vomiting resulted. She had had to sleep on one occasion, when the weather was very cold, without any fire in the house and with all the windows open. Chief Hosmer had visited the place and had not dared to go into the cellar with a lamp.

"Mr. R——, of 3 Salem Street, said his wife and himself had been made very ill from the gas. That was last winter; he

had not noticed it as much this winter. He had been afraid several times that the house would be blown up because it was so full of gas, and he considered it highly inflammable. He had illuminating gas in his house. In the summer months the gas was hardly noticeable; it was when the thermometer lowered that the odors were strongest.

"Mr. C——, of 31 Cross Street, said there was water in his cellar after a heavy rainfall, and that the odors were noticeable after the inflowing of the water.

"Mr. L——, of 27 Cross Street, said that Dr. Johnson had advised him to move from his home if it appeared that there was no remedy for the unhealthful condition of affairs. He thought it was too bad if a man who owned his home should be compelled to move out of it simply because the Gas Company would not attend to its work.

"At the conclusion of the remonstrants' testimony, Agent Knapp said that the stories of the previous persons were not exaggerated in the least.

. . . .

"City Engineer Bowers was then asked to explain the case as he knew it. He said that the Gas Company had run a sewer through their property long before there was a system of sewerage in the city. In 1881 the Locks & Canals Company had prohibited the Gas Company emptying refuse into their canals. Ever since that time, said Mr. Bowers, at times of low barometer and wet weather, people had been troubled with the presence of gas in their cellars. The city had received so many complaints with regard to the matter that the Gas Company had been told that a remedy must be effected.

"He then told of the large gasometer which had been abandoned by the company but which is full of a residuum which results from the gas-making process. That gasometer was 83 by 21 ft. in size. In the past year nearly around the entire gas plant a city sewer had been constructed, but he said the old Cross Street sewer had been cut off. The end of the trouble was confidently expected then, he said, and for three weeks not a complaint came in, then things began to take on a worse aspect than ever. He had gone to the plant three weeks ago and found everything in a hubbub there.

"'The only thing to do is to dig up the old sewers near the gas works and to build new catch-basins there and to lay new sewers which are perfectly tight. There are some leaks in a few of the pipes. The yard is concreted, and that concrete will have to be dug up. In cutting off the old sewer the yard has been filled with water almost up to the boilers in the engine-room.'

"He said that the soil about the plant was like a sponge, filled with a molasses-like fluid which leaked out of the abandoned tank. The stagnant water around the yard is filled with gas, he said.

"The peculiar part of the whole affair is that although the cause of the gas can be accounted for, it is not within the range

of possibility to say how the odor gets a half a mile from where it emanates and in that half-mile stretch before it is noticeable in Suffolk Street there are many, many houses that have never had one bit of gas in them.

"On a question from Mr. O——, Mr. Bowers said that the gas which had been found in the Massachusetts Mohair Plush Company's works was the same as that which had been detected in Suffolk Street. Many years ago there used to be trouble in Moody Street, but that had not been reported for a long time."

"FEBRUARY 5, 1903.

"The members of the Board of Health, Major Thomas O. Allen, City Engineer Bowers and Superintendent Hintze of the Gas Company, looked over the works of the Lowell Gas Company, in School Street, yesterday afternoon, with relation to the gas nuisance, and to see if a plan for the removal of the disagreeable deposit in the old tank might be hit upon. Nothing definite with regard to a plan was struck and probably will not be until the next meeting of the board, Tuesday afternoon of next week.

"The delegation arrived at the works about 3.30 and was immediately put in care of Superintendent Hintze, who showed the tar substance which is said to be the cause of the odor in the houses in the vicinity of Suffolk Street. It is a tar product. There is a little doubt about it. The olfactory nerves of the members of the board were strained as the different ones took long smells of the samples dished up from an old repository. It was decidedly disagreeable to smell, and one and all agreed that if such an odor permeated the houses of people it must be immediately abated.

"The huge tank, now abandoned, which is said to hold 800 000 gallons of the strong-smelling stuff and water was next visited and walked over. Superintendent Hintze said that the tank which holds the stuff is a little over 21 ft. in depth and 83 ft. in diameter. Nineteen ft. of the depth is largely water, the 2 ft. of deposit on the bottom of the tank is rank-smelling tar product and is forced out into the ground. That the soil about the plant is thoroughly saturated with the syrup-like stuff not anybody will deny.

"The building in which is the tar product will shortly be demolished and the Gas Company officials are in as great a quandary as is the Board of Health.

"The idea of distilling the substance seems temporarily abandoned, although Mr. Hintze said that the company could, without a doubt, make money by distilling it. Aniline colors are present in it; and various tar products, such as musk, asphalt, carbolic acid, etc., could, according to Major Allen, be obtained from it if a process could be determined upon. The stuff is a vegetable decomposition, traced back to its origin from coal. Combined with it are, of course, foreign ingredients which must be eliminated.

"Hundreds of plans have been thought over by those inter-

ested in the matter, and it now seems that the only practicable one is to run the pipe-line. The matter will be threshed over again at the next meeting of the Board of Health."

"MARCH 24, 1903.

"The gas nuisance in Cross Street has been abated as far as Cross Street and Lowell are concerned, but a report from down-river assures us of trouble ahead for the Gas Company from the city of Lawrence.

"The gas nuisance disappeared from the public nostril a week or more ago and for a time no one knew or cared how it had been abated.

"A week or so ago the experts employed by the Pacific Mills began to notice a peculiar stain in some of the goods produced at that mill, according to report, and upon analyzing it found it to be caused by tar.

"An investigation followed, which showed that tar refuse was being carried down the river and was responsible for the trouble, while further investigation showed that in certain places the banks of the river were lined with a mysterious foul-smelling tar deposit."

It was found on investigation that this nuisance was due, not to the discharge of a weak ammoniacal liquor from the upper 12 ft. of No. 3 holder discharged into the canals at Lowell, but to the collection of tar wastes, which had been deposited on the banks of the Merrimac River and carried down stream by the rising river.

During 1903 and the early part of 1904 a good deal of progress in disposing of the daily waste products of the gas houses was made when Mr. Harry W. Clark was called in to advise the Gas Company with reference to filtering the waste products of the water gas, and coke filters were built, which took care of those wastes as long as they were not overcrowded with the contents of No. 3 holder, a part of which was occasionally added by the officials at the works to the regular amount, and the effluent run into the sewers before being properly treated. These filters were 33 ft. long by 15 ft. wide, in three compartments. In the first one the oil and tar were separated out as far as possible and burned and the residue filtered in the other two compartments through 3.5 ft. of coke, the effluent running into a 6-in. tile Akron sewer which discharged into the city sewer in School Street. Twenty thousand gal. per day on these filters would correspond to about 2 000 000 gal. per acre per day through these. This amount was gradually reduced so that, during our work, the amount treated was considerably less than

10 000 gal. per day, and is still less than this now that the Company is making a larger percentage of coal gas.

The most serious part of the trouble from gases and odors during 1903 I now think was due, not so much to the effluent from the wastes produced daily, but to pumping the ground water during the construction of the new retort house built that year directly into the sewers, and if it had not been for this new condition and the overloading of the filters with accumulated wastes from No. 3 holder, the ordinary daily wastes could have been taken care of without difficulty, leaving only the balance of the liquid in No. 3 holder and that in the ground to be gotten rid of.

Sometime after the first of May, 1904, the Lowell Gas Company, after giving me a general outline of the troubles and the remedies suggested, including a large sewer in the bottom of the canal, asked me to examine the conditions at the yard and report upon some plan which could be carried out to remedy the nuisance. I asked Mr. Harry W. Clark to take this matter up with me from the chemical standpoint, and after considering both the engineering and chemical problems, we came to the following conclusions:

The fearful odors in the city sewers, most of them near Suffolk Street and Broadway, were caused by the breaking up of certain coal and water gas tar products and oils which were discharged or found their way into the city sewer in Western Avenue. These waste products appeared to have gotten into the sewers from the Gas Company's yard in a good many ways:

From the old holder pit No. 3 by leakage.

From the surface and ground near the old tar tank.

From the ground at the site of the new retort house during construction.

From the regular daily wastes.

Added to these sources of trouble was the occasional flooding of the yard after storms, adding to that in the ground comparatively clean water, which, getting into the ground, got mixed with the tar wastes there and became unfit to be drained into the sewers without filtration.

It seemed best to us to recommend that the Lowell Gas Light Company begin at once on a definite plan which, when finished, should accomplish the following:

1. Get rid of the contents of the No. 3 holder pit and dry up the bottom.

2. Clean up the ground in all parts of the yard, and provide for keeping it clean.

3. Build a system of tight storm and surface water drains and catch basins to take all clean roof and surface water.

4. Provide tight storage tanks for taking by-products, drips or refuse of any sort.

5. Provide additional filters to remove any objectionable matters produced in the yard so that the effluent would be fit to go into the sewers.

6. Concrete the surface of the yard, so that all roof, surface and snow-water should not get into the ground.

1. *Contents of No. 3 Holder.* — At the time of beginning work, about September 1, 1904, the contents of No. 3 holder had been reduced by leakage and drawing through the filters to 8 ft. in depth, of which the bottom 2 ft. was a black liquid, mostly tar, about the consistency of paint or slush. The upper 6 ft. was a dilute ammoniacal liquor which, as the draft on the coke filters was gradually reduced, was pumped out, filtered and the effluent discharged into the city sewers. The tar in the bottom was mixed with fine coke and burned under the boilers. The pit is now free of all objectionable matters and is used for storing coke.

2. *Cleaning Up the Ground.* — This work was done at two places where the excavation of large amounts of material made it necessary to pump constantly, as well as where digging was done for the drains; and the fact that this work covered three years was a fortunate circumstance for us in a good many ways. The work on the drains covered portions of 1904, 1905 and 1906; the sedimentation tanks were built in 1904 and the new tar tank in 1905. They will be referred to in order of their importance as far as the condition of the ground went.

Old Tar Tank. — The worst place in the yard was the old wooden tar tank occupying the middle of the north side. It not only contained the manufactured coal gas tar which settled to the bottom and was pumped into barrels and sold, but, on top of the tar, about 4 ft. of ammoniacal liquors of various strengths, depending upon the amount of surface and ground water which worked into the tank after storms. The top of this tank was the lowest place in the yard; it was covered with water after a storm; it was unsightly and maintained a pretty nearly constant head on the ground and sewers. It had been such a nuisance that the Gas Company did not wish another tank in the ground, but preferred to build it of steel above the surface. However, as the sedimentation tanks when built were found to be tight, it was decided to build a new covered tar tank of concrete in the

ground south of the retort house, and this was finished in the fall of 1905. The old tank was used through 1904 and 1905, until the completion of the new one, but after the new one was ready to receive the tar and ammoniacal liquors from the works the old one was gradually drawn down, the tar sold and the liquors drawn off and purified through the filters. When it was finally emptied, in 1906, the tank was filled up with good material and the ground graded up. After the frost is out of the ground this spring the surface of the ground above this old tank will, I hope, be concreted and this area will no longer be an eyesore to everybody.

New Tar Tank. — The new tank was built of reinforced concrete 100 by 40 by 10 ft., all inside dimensions, in the yard just south of the retort house. It has one solid partition across the tank, 12 ft. from the west end, with three pipes controlled by gates through it to draw ammoniacal liquor from the main tank into the end compartment at different levels. The material excavated from the site of the new tar tank was composed of ashes, cinders, ledge and the remains of several old walls, retorts and pits. The ground was full of tar, and in one place a subterranean area was discovered connected with pipes which were full of thick coal tar.

The important thing here to look out for was to get all the liquids in the ground within reach pumped out and filtered before they were discharged into the sewers. The following clause was a part of the contract: "The work shall be kept as free as possible from water or other liquids, and all objectionable matters removed before the waste liquids are put into the sewers to the satisfaction of the Lowell Board of Health or the city engineer. The Lowell Gas Light Company will furnish any necessary steam or electric power for pumping or drilling and take the liquids from the new sedimentation tanks to which the contractor will pump them, and provide such other facilities for purifying the liquid as the engineer may think necessary for the proper carrying on of the work up to the time set for completing the contract, and one month in addition if the contract is not completed by September 1, 1905; after that time the contractor shall assume all responsibility for handling and pumping the water or other liquids."

Pumping went on steadily through the progress of this work from the ground into the sedimentation tanks which were built the previous year, and the liquid was filtered before the effluent was discharged into the sewers. No trouble was experienced

from the people living on the line of the sewer excepting at one time when, through carelessness, for one day some water from the site of the tank got into the sewer without being purified. For a short period before the steam pump was put into commission hand-pumping was used and the ground water filtered through some rude filters, simple boxes of coke, into which the liquid was pumped.

The work was let out by contract and, including excavation, rock, pumping, forms and concrete, cost about $16.50 per yard of concrete in place.

The roof of this new tar tank was figured to have coke piled upon it, and now that the top has been covered with tar concrete at the finished grade of the yard it has served its purpose well as a storage tank for tar and ammoniacal liquors without taking away any of the area of the yard, which at present is very necessary. There was no indication of leakage on the inside of the tank when empty, excepting a little moisture, and the liquors in it are securely bottled up.

Sedimentation Tanks. — As already mentioned, I have not taken up these in chronological order, as they were finished before the drains and tar tank; these storage or sedimentation tanks, occupying a portion of the west end of the yard near School Street, were begun during September of 1904 and pushed during that fall to completion as fast as possible in order to provide some means for taking care of the waste products in the ground and the daily wastes if the filters were out of commission. The entire structure is an open L-shaped four-compartment concrete tank with overflows 2 ft. wide and 18 in. below the top; the walls are 48 and 50 ft. on the long sides, 24 and 16 ft. on the short sides and 10 ft. deep below the ground. The capacity was increased somewhat over Mr. Clark's original design on account of the size of the cofferdam and the location of some old holder walls which were found in the excavation. As built the compartments had the following capacities:

A	32 119 gal.
B	17 802 gal.
C	15 708 gal.
D	23 038 gal.
Total	88 667 gal., or

about 9 days' supply, at 10 000 gal. of waste daily.

These tanks were built partly in quicksand and partly over the bottom of old No. 1 holder pit which had been abandoned

for a good many years. The material below the concrete bottom was excavated for a depth of about a foot and refilled with cinders with tile drains leading to a pump hole outside of the tanks. This was kept open for a number of months after the tanks were finished.

The total cost, including excavation, cutting out old walls, rock, building forms and concrete, pumping, etc., was at the rate of about $17.80 per yard. The concrete was not reinforced excepting in one or two places.

During the construction of those tanks the ground was pumped constantly, and all the water from the site of the tanks and for a considerable distance around was pumped clear. It was found that the tanks occupying the site of the old No. 1 holder pit contained a yellowish liquor smelling of ammonia. This was all pumped to the filters and taken care of before going into the sewers. During the next two years these tanks were used to store all wastes, of any sort, which were drawn from the ground or the gas houses excepting what was put into the tar tank.

3. *Drains.* — This work consisted of a general system of tight drains 6 in. to 18 in. in diameter, of deep socket Akron pipe laid with cement joints. They were designed for surface and roof-water only; there was, however, one exception to this rule, a 6-in. drain with open joints on the north side of the upper end of the coal shed. This was put in to intercept clean ground water coming out of the broken ledge at this end of the yard. These drains took the water from the yard by means of tight concrete catch-basins, 4 ft. in diameter and about 6 ft. deep, from 50 to 80 ft. apart, with square iron covers 0.40 ft. below the finished grade of the tar concrete surface of the ground. The drains were figured to discharge as fast as possible the rain falling on one half the roof of the coal shed, the new retort house and the yard. As a basis for this, I divided the yard into seven different areas, which naturally or by grading could discharge over the surface into the proposed drains, and assumed for purposes of calculation that 4 in. of rain might have to be taken care of in 24 hr. and that for a portion of the time it might come at the rate of 2 in. per hour. The sizes were made large enough to carry these amounts without the water being backed up much above the overflows of the catch-basins. It required a possible total of 11.08 cu. ft. per second, or at the rate of 7 164 000 gal. per day during the worst part of the storm. The 10 000 or less gallons a day of manufacturing wastes look very small compared

with this. With the yard full of pipes, and several trials necessary before a straight line could be settled upon, it was not possible to follow out a definite scheme of grades, but the pipes were made a little larger than the scheme called for if the grades were flat, to take off the amounts of water already mentioned. No grade much less than 1 per cent. was used.

The conditions assumed for sizes and grades were made extreme ones because a part of the plan included finally tar concreting the surface of the ground, which, with the roofs, would make the conditions such that the water would get into the sewers and out of the yard as soon as possible after the fall of the rain. These drains were laid at different times during the years of 1904, 1905 and some little cleaning up work during 1906. Any tar or other wastes met with in the ground during the digging for and laying these sewers was pumped to boxes filled with coke, and the tar and oil filtered out and burned, the effluent going into the sewers. The sewers were laid as low as the city sewer in School Street and the overflow into the canal would allow.

The standard prices for this work which were made to cover the three years were as follows:

18 in.	$1.00 per linear ft.
15 in.	0.90 per linear ft.
12 in.	0.80 per linear ft.
10 in.	0.70 per linear ft.
8 in.	0.60 per linear ft.
6 in.	0.50 per linear ft.
Manholes	$32.50 each, complete.
Catch basins	$27.50 each, complete.
Masonry and rock in trenches taken out	$5.00 per yd.

All special and extra work at cost as approved by the engineer, plus 15 per cent.

The extra work due to necessary changes in line in this contract were very large, but the work was well done under great difficulties.

4. *Tight Storage Tanks.* — These included the sedimentation tanks and new tar tank already described in connection with cleaning up the ground.

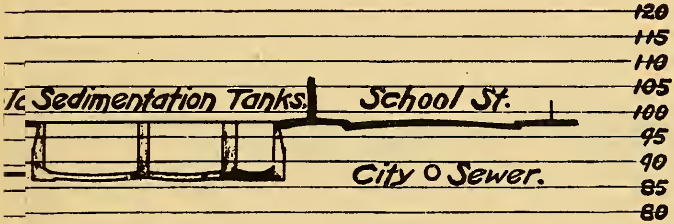
5. *Additional Filters.* — The original design called for larger filters to be located just north of the sedimentation tanks and to be used in connection with them. It was found, however, after taking care of the wastes during the three years, that the present filters were large enough, until the output of gas increased

eas Light Company

d Yard East of School Street

ccompany Report of Arthur T. Safford
t Consulting Engineer

February 28, 1907.

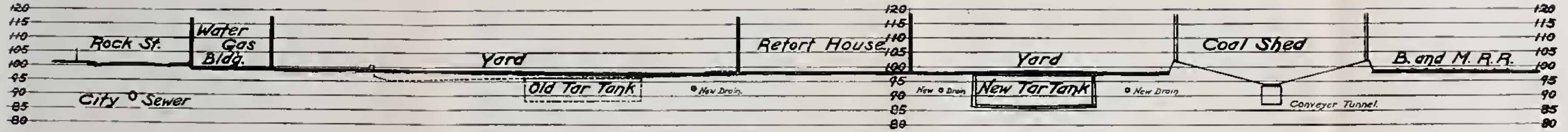


St

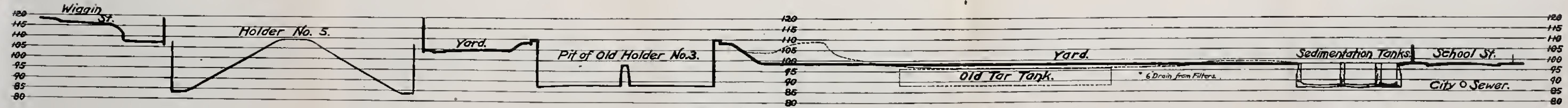
Lowell Gas Light Company

Sections through old Yard East of School Street
Feb. 23, 1907.

To Accompany Report of Arthur T. Safford
Consulting Engineer
February 28, 1907.



Section North and South from Rock Street to B. and M. R.R. Tracks.



Section East and West from Wiggin Street to School Street.

materially beyond what it now is, and the building of these filters has been put off until they are necessary.

6. *Tar Concreting.* — The final work has been to concrete portions of the yard, particularly around catch-basins, with a 3-in. base of stone and tar and a top dressing of coal tar and sand heated to the proper temperature. The surface of this was laid to an exact grade, the catch-basins being left in a hollow 0.40 ft. deep. This concrete covers now most of the lower yard, including everything south of the retort house and a strip beyond the catch-basins on the north side. After the material filled into the old tar tank has settled properly and the rough grading is ready, this work will be continued until the lower yard will be entirely concreted. The cost of the work was from 70 cents to $1.00 per square yard.

The yard now has been worked over and pumped so thoroughly that it is possible to dig anywhere and, if there is any ground water, find it reasonably clean; the filters, operating for a portion of the week, take care of all the waste liquors except the water-gas tar and oil, which are burned, and the coal-gas tar and ammoniacal liquors, which are sold. The sedimentation tanks are kept for an emergency, with connections to all the different parts of the coal and water-gas plant.

This description covers the work, which has been done since 1904, and which has not only gotten rid of the troubles from gas wastes, but improved the looks of the yard and made the yard room available.

The location of the different structures in the yard east of School Street is shown by the plan used as a working drawing during the construction of the drains, and the elevations of the yard, holder pits, tanks, etc., are shown by two sections, one north and south through the yard, and the other east and west. The old conditions are shown by dotted lines, the new oı finished grades by full lines.

Since the completion of the work and writing the first draft of this paper I have taken the time to look up all the references to troubles due to gas wastes abroad and elsewhere in this country which were given in the gas journals of Great Britain and the United States. There are very few such references, and the causes of the troubles and the remedies are mostly local in their application, as in the case of the Lowell Company. I have found no evidences of tarry matters having been actually separated out and discharged into sewers, but dilute ammoniacal liquor and

waste products containing small amounts of tar and oil have been. There are probably two reasons for the few published records of trouble,—the common idea that anything can be put into sewers, and the unwillingness on the part of gas companies to acknowledge that the bad conditions are produced by the wastes from their works. Most of the common objections to gas works are on account of smells, noise or smoke; these offend the senses but do not often do more than this. Smells which may be offensive to some are not noticed by others, and children of the present generation in Lowell have been taken to the gas works and held over the tar tanks when troubled with colds of a croupy nature.

Among the different published reports there are two which have more than a local interest, and at the risk of making this paper too long I have included portions of them, as they represent similar conditions elsewhere.

The first is an article by John Radcliffe with regard to certain troubles from ammoniacal liquor and its waste products from the gas works at Sutton (Surrey), England, and their treatment. It is published in the English *Journal of Gas Lighting, Water Supply, etc.*, in the number of October 2, 1906. It is of special interest on account of the effect upon the Sutton sewage beds and the reference to Mr. Dibdin.

* "Gas, coke-oven and chemical works which make large volumes of this waste product now find it difficult to dispose of without trouble ensuing with one or other of the various authorities with whom they may come into conflict, and those works are exceptionally situated which find themselves able to safely select one of the several means available.

"When the works were fewer in number and the temperatures of distillation were not high in degree, no doubt the liquor was discharged and eventually entered the natural channels, which are water courses, without unduly depreciating their value for any purpose, but with the development of the industries and the attainment of high retort temperatures, the accumulation of injurious substances, more particularly phenolic bodies and compounds of cyanogen, can be so great that the river boards, fisheries commissions and sanitary and water-supply authorities have been obliged to call attention to the damage and injury which may be done. In a large number of instances prohibition of discharge from works has been issued. There are works which have found it necessary to cease the distillation of ammonia, shut down the plant and sell the liquor for whatever it will bring them. And there are indications leading to the conclusion that the river boards in different parts of the country will no longer

* "The Difficulties of Disposing of Ammonia-Spent Liquor, and Certain Results of Its Purification." By John Radcliffe.

permit the discharge of the spent-liquor into watercourses indirectly or directly. Works placed on the coast as a rule have nothing to fear, but others on estuaries which are fishing grounds have had to avoid discharging the crude effluent to the sea.

"Some works situated inland allow it to percolate the earth, and where the underlying strata are deep and porous the method is a safe one. But if shallow, that is to say, if the effluent cannot sink below the level of streams adjacent, it is bound eventually to appear in them. Fortunately or unfortunately, the analytical test for the most objectionable of its constituents is extremely sensitive and unmistakable, so that the presence of spent-liquor can be ascertained with certainty and its proportion inferred.

"Other works are obliged to have recourse to very expensive evaporation until solid residue is obtained which is carried away. Sometimes a portion of the evaporation is done in boilers for steam raising, to the damage of the fittings, and is a mere postponement of the trouble. There are coke-oven plants using again for gas-washing the liquor from which the free ammonia only has been removed, and the cycle of operations is continued until the ammonia-liquor is saturated with fixed ammonium salts. It is then decomposed with lime and a concentrated spent-liquor obtained. This is evaporated and the solid residue is carried away as in the previous instance. But these residues still contain all the objectionable impurities of the original liquor. If the mass is buried, being deliquescent, it soon becomes fluid and drains away unless confined in water-tight pits. If thrown on to the land, it must be percolated through the earth by rain and washed into watercourses eventually, and then the distiller arrives at exactly the same end (after spending a lot of money) as if he had pumped the spent-liquor on to the land or run it into a stream.

"There is much difference of opinion as to what is the effect of spent-liquor upon sewage treatment when passed into the works' drains, and as in most cases this method of disposal will be the readiest and most convenient, it is necessary to more closely consider it.

"If the subsequent treatment of sewage consists in the removal of solid matter by lime and materials of a similar character, the cyanogen compounds will remain in solution, and the prohibition of the River Boards against discharge may be applied. If the treatment consists in pumping the sewage upon land to be afterwards cultivated, the spent-liquor in some instances has not been found to hinder vegetable growth, but in most cases has been found to seriously interfere with it. The result will depend upon the proportion present and its composition. Usually the proportion of the spent-liquor will be under 1 per cent., and should it hold about this amount, and the liquor contain under the equivalent of 0.15 per cent. of ammonium sulphocyanide and be free from tar particles, with the phenolic compounds low in amount and be not immoderately alkaline, the probability is that

cultivation will not be interfered with and the bacteria of the soil and the sewage will be able to decompose the salts of the liquor. If, however, the water supply is only a small one and the proportion of liquor increased, or, as is usually the case, has a larger amount of injurious compounds present than that indicated, vegetable growth will be retarded, or even prevented, the sewage matter will not be quickly absorbed and the salts of the liquor will remain longer undecomposed, with the serious consequences of both remaining a dangerous period of time on the land with all the accompanying risks.

"If the system of treatment is the modern one of septic tanks the same remarks apply as in the previous instance, and each case must be considered in relation to all the circumstances of it. The consequences will be dependent upon the proportion of spent-liquor, its composition and the degree of aëration arrived at in the beds. It is obvious this must be the case. There are exceptional instances of works which have passed their liquor to bacteria beds without damage to them being reported, but statements have been made in general terms that this material is not injurious. The experiences of the Sutton (Surrey) Gas Company may be cited to show otherwise. The double-contact bacterial beds for the treatment of sewage were first devised by Mr. Dibdin, who originated the system, and the first beds in this or in any country were put down at Sutton twenty years ago and have been a model for all others. Public bodies from all parts of the world have visited and copied them. The engineer at the time of the inception was Mr. Chambers Smith who, during the whole time up to the present, has had the system under his charge on behalf of the district council.

"The Sutton Gas Company up to March, 1905, sold their ammoniacal liquor. In April they had built a sulphate-house, put down a new sulphate plant of the most modern type (the devil liquor being redistilled) and began to work it. The spent liquor was passed to the sewers. Compared with some others it may be said to be a rather harmless liquor, containing the equivalent of 0.15 per cent. of ammonium sulphocyanide and a proportionate amount of other impurities. The volume added was 3 per cent. Soon after the plant started it was reported that the quality of the sewage-effluent had become deteriorated. Reports are regularly made. In a few days the sewage-effluent had a foul smell and the beds became completely ineffective. The medical officer of health (Dr. Bower) examined them and found that most of the bacteria were killed and those that were not dead were undeveloped, enfeebled visibly and ineffective. The sulphate plant worked for three weeks and then stopped, and the trouble at the sewage beds thereupon vanished. The gas works went back to their practice of selling ammoniacal liquor and the trouble at the beds did not recur. It appeared that the company were not correctly informed of the volume of sewage with which the liquor would be mixed. The experience of the Waltham Abbey Gas Company is precisely the same. The sul-

phate plant was stopped nearly two years on account of the same difficulty. It seems in many cases that, if ammonia plants are to work at all, a process of liquor purification is essential.

"In August, 1905, the Sutton Gas Company, who were standing to lose a lot of money, instructed the writer to put down a purification plant, which began to work in September. It fulfilled the requirements in being inexpensive and simple, and resulted in the continuous and automatic removal of free lime, tar particles, organic ammonia, sulphocyanides, cyanides, ferrocyanides and sulphides, and also compounds of dithiocyanogen, which the writer has observed in many samples of spent liquor. Samples of the purified effluent were submitted by the council to Dr. Bower, who reported: 'To various proportions of crude sewage from the farm were added 1 per cent., 5 per cent. and 25 per cent. of the purified effluent from the sulphate of ammonia plant, and cultivation experiments made. I found that bacterial growth was not appreciably inhibited by any less quantity than 25 per cent. of the effluent.' The Clinical Research Association also reported to Dr. Bower as follows: 'A 1 per cent. dilution is without action on the colon bacillus, which, in fact, grows freely in nutriment broth containing this amount of fluid.' The Gas Company sent samples to Dr. Otto Hehner, who reported:

"'I procured some sewage effluent from the Metropolitan Northern Outfall Works at Beckton, and added to measured quantities of it (after straining out the coarser particles by filtration through cotton wool) various proportions of the (purified) ammonia plant effluent. These mixtures I kept at about 23 degrees cent. (a little below blood heat) for some 5 hours, so as to give to the chemicals contained in the liquor a due chance of injuriously affecting the bacteria. I at the same time incubated a sample of the sewage without addition of effluent. From each incubated sample I then prepared dilutions from which I cultivated gelatine plates and agar plates, the former at ordinary temperature, the latter at blood heat. The number of colonies that had developed was ascertained, and the results are stated in the following table, in which due allowance is made for the dilution of the sewage by the addition of the purified gas effluent.

GELATINE CULTURES.

	Total No. of Bacteria per Cu. Cm. of Sewage.
Sewage without addition	2 419 000
Sewage plus 4 per cent. of purified effluent	2 337 000
Sewage plus 6 per cent. of purified effluent	2 475 000
Sewage plus 8 per cent. of purified effluent	3 211 000
Sewage plus 12 per cent. of purified effluent	3 846 000
Sewage plus 16 per cent. of purified effluent	3 717 000

AGAR CULTURES AT BLOOD HEAT.

Sewage without addition	1 058 000
Sewage plus 4 per cent. of purified effluent	1 576 000
Sewage plus 6 per cent. of purified effluent	1 800 000
Sewage plus 8 per cent. of purified effluent	1 844 000
Sewage plus 12 per cent. of purified effluent	2 933 000
Sewage plus 16 per cent. of purified effluent	1 753 000

" 'It is abundantly clear from the above results that this effluent, when added to sewage in proportions up to 12 per cent., has not only not antiseptic bactericidal action, but greatly stimulates their growth and development, almost twice as many bacteria developing in gelatine and three times as many with agar at blood heat in the presence of 12 per cent. of liquor than in sewage alone. It is clear that the liquor furnishes some food materials to bacterial life.

" 'When the proportion of effluent exceeds 12 per cent. a slight inhibitive effect begins to appear, but even with 16 per cent. the bacterial development is considerably greater than in pure sewage. The discharge of purified effluent of the nature of the sample upon which I experimented into the Sutton sewers therefore assists the proper working of the bacteria beds in which the sewage is treated, and is without the least injurious influence.'

" This conclusion was placed before Mr. Dibdin, who stated that when sufficient of the poisonous substances was removed the bacteria would be able to decompose and feed upon the remaining salts.

" Upon the strength of these reports the Gas Company, who had in the meantime been using the purified effluent for works purposes, passed it into the drains in the same proportion as before, viz., 3 per cent., and the results have justified expectations. It has been going to the beds right up to the present time, and Mr. Chambers Smith has stated there are no complaints to make. The sulphate plant works three weeks and stops two, and an observer who regularly sees the sewage effluent vouches that when the purified liquor is passing to the beds the quality of the sewage effluent is improved. As the proportion added will always be under 3 per cent., and in most cases 1 per cent., the effectiveness of the treatment is apparent, as 25 per cent. can be safely added. A similar purification plant is now working at Waltham Abbey and the results are equally good. The Corporation of Coventry are adopting the process for their new works at Foleshill and other works also.

" I think it can now be stated that ammonia-spent liquor in some instances injures bacteria beds, and further that it is possible to purify it with the result of its being beneficial. Purification, indeed, affords the simplest solution of the problem."

This article quoted is valuable not only for its contribution to the general knowledge of the subject, but for its promised remedies for the bad effect of gas waste liquors on those communities where sewage disposal, other than the discharge of crude sewage into streams, is necessary. I only wish I could report from personal knowledge of the good results which have apparently been obtained at Sutton, England.

With reference to published reports of troubles from gas refuse in this country, I have included extracts from a very interesting paper by Frederick H. Shilton, of Philadelphia, Pa.,

who built a gas plant near a discriminating neighborhood and arranged for the disposal of the wastes with the idea of reducing to a minimum the nuisances of all kinds. This paper is published in the *American Gas Light Journal*, March, 1899, page 337. My notes were made under difficult circumstances and there may be some errors in the extracts. He says that "a gas company must conduct its business and operate its plant in such a way as will not injure its neighbors." He defines a nuisance as "that which offends an ordinary man but not a delicate-nosed one." The following have been ruled as nuisances: "Pollution of private wells adjacent; the pollution of state streams; pollution of rivers used for water supply; emission of noxious fumes destroying vegetation; emission of smoke, cinders or odor, steam and other noxious vapors; grit of heavy machinery."

According to Mr. Shilton, smell comes from various causes:

"1. Leaky oil tanks.
"2. Saturated earth from oil drips.
"3. Drip water not properly disposed of.
"4. Foul water by blowing of holders.
"5. Escaping gas from purging water gas refuse.
"6. Escaping gas from opening purifiers.
"7. Vapor from spent lime or foul oxide.
"8. Tar wells.
"9. Tarry sawdust or breeze from purifiers."

Offensive drainage may come from

"1. Unintercepted scrubber or condenser water saturated or laden with ammonia tar or oily scum.
"2. Tar or oil wasted.
"3. Rain washings of spent lime or old oxide.
"4. General gas works and surface drainage.
"5. Drip water not properly disposed of."

In the design of this particular plant the following provisions were made for offensive refuse and drainage:

"All water used in scrubbing, and all water that comes from the various seal pots, overflows, etc., containing whatever tar or oily refuse matter is made in the process of manufacture, is led to tar separators already mentioned. These are rectangular, well-made wooden tanks or vats buried in the earth, saving removable plank closely fitted tops. They are so designed with proper partitions, baffling boards, compartments, etc., that the water flowing in them passes through but slowly, and in this passage the tar is intercepted and precipitated to the bottom to be afterwards pumped out into barrels and sold or otherwise disposed of. If any free oil appears on the surface it will be

caught and skimmed off and returned to the oil tank. The water after being cleaned as above is then pumped back by a circulating pump and used over and over again through the scrubbers and seal pots as before. The result is that no considerable quantity is constantly flowing off or consumed, but a small amount, say 3 or 4 gal. per 1 000, needs to be taken care of. This is so clean that it is allowed to go into a small creek in the rear of the works, as no pollution ensues. An ordinary cesspool takes care of the office and closet drainage."

The general conclusions which can be drawn from a study of this problem, and the results of the work at Lowell, Mass., and elsewhere, are as follows:

The ordinary wastes of a coal and water gas plant can be taken care of within the works by separating and burning the heavier matters and treating chemically or filtering through coke the lighter liquids, and the effluent will not cause trouble in the public sewers, but this effluent should be treated specially if the sewage is disposed of on land.

Storage tanks for several days' waste, which are perfectly tight, should be provided against breakdowns in the collection of waste products, and should be divided into compartments, with overflows, in order to separate the wastes whenever necessary.

If the ground within the yard is porous and there are old wastes of an objectionable nature which have accumulated, these should be filtered through coke before being discharged, and for the best results a separate system of storm water drains should be provided to include roof water as well as surface water; if it is necessary to keep the ground entirely clean the yard may be concreted.

I wish here to express my obligations to Mr. Arthur C. Pease, the former superintendent of the works, who died of pneumonia about the middle of January. He was not only of great help to Mr. Clark and myself in working out these different problems, but designed and put into operation the scheme for burning the oil and tar from the water-gas plant by spraying them under the boilers. He had agreed to speak for the manufacturing side before the Society at this time, and this discussion will not be as complete as I hoped it would be.

DISCUSSION.

MR. H. W. CLARK. — Mr. Safford has told you nearly the entire story in regard to cleaning up the Lowell gas nuisance and

the methods followed to get rid of the objectionable waste liquors in the old holders and in the ground. When I was first called into this case by the president of the Lowell Gas Company it was presented to me as a very small problem compared with what it developed into later. The bad repute into which the plant had fallen among those living in the neighborhood or connected with the same sewer was stated to be due entirely to the waste products from the water-gas plant, and I was at first asked to study only the wastes from this plant. I found that water gas made in the usual way had the usual tarry and oily waste liquid. In making water gas, the wastes from the gas machines collect in and pass through what are known as seal pots and consist of water, light and heavy oils, tar and tarry matter. The amount of this liquor produced per million cubic feet of gas made per day varies, but in such plants as I have had opportunity to examine is about 12 000 gal. per million feet of gas. From these seal pots or water seals at the Lowell plant the water oils and tarry matters flow into what is known as the tar settling tank or separator. A certain separation of tar, water and oil occurs here, and from this tank the water is continually pumped back into the water seals. Into this tank a certain amount of condenser water is also collected. There had been installed at that time by the gas company, to treat the waste liquors accumulating in this tar-settling tank, a plant designed by a certain sewage disposal company, so called. This plant consisted of two small concrete settling basins about 6 by 3 ft. and 2.5 ft. deep, a third settling basin of about the same size to which the liquid went after passage through the first basins and coke strainers about a square foot in size and a few inches thick. Near these tanks were two sets of filter beds with a total area of 400 sq. ft., the material of these beds being a mixture of sand and coke breeze and the depth of the beds about 3.5 ft. To these the liquid was passed after the preliminary treatment. The plant was guaranteed by the sewage company, so I was told, to care for 5 000 gal. of waste daily. One sample only of the effluent of this plant had been collected by the filter company, so I was told by the superintendent of the gas works, and that on the first day of its operation. It is needless to say that it was "clear and colorless," as all such samples collected for a special purpose are always stated to be. I believe it was not claimed to be odorless. After running about a week these filters became badly clogged with tarry matters, and consequently when I first saw them they had been out of use most of the time since their con-

struction. The effluent passing from them had the strong, penetrating and disagreeable odor objected to by the surrounding community. At the time I was consulted there were 10 000 to 12 000 gal. of this liquor to be disposed of each day. It was evident, of course, from the composition of this waste liquid, that its treatment was not a question of purification by filtration, that is, by bacterial filtration, but rather one of precipitation and straining. I found after making a few experiments that lime was the cheapest and most efficient precipitant to use, and that by its use a good precipitation could be obtained with 3 000 to 4 000 lb. per million gallons, or in actual amounts 30 or 40 lb. per each day's production of waste liquor at the Lowell gas plant. Adding a lime tank, introducing milk of lime to the waste after it had passed through a preliminary settling tank and increasing the size of the coke strainers resulted in good precipitation and oil removal and the production of a fairly clear, yellowish or brownish liquor with its suspended matters removed by the precipitant, most of its oil caught by the coke and the liquid much reduced in odor. The application of this to the filters has given an end liquor that is fairly clear and certainly free enough from odor to be run into a city sewer, and that was the only requirement at Lowell. The tar collected in the tar tank and that in the sedimentation tank is pumped out from time to time, mixed with coke and used for fuel at the gas plant. As I have said, this was the only part of the works that I was at first asked to improve, if possible, and not until considerably later did the Gas Company conclude that the whole problem, ground water, leakage from abandoned holders, etc., must be studied in a broader way. Mr. Safford has told the results of this later work. Since the Lowell work I have had occasion to study similar gas liquor problems at other places. At Paterson, N. J., I found that the water-gas waste was one of the chief industrial wastes aiding in the pollution of the Passaic River, although they had quite an elaborate system of so-called separator tanks with baffles arranged to hold back the tar and prevent the passage of light oils upon the surface of the liquid. At the Paterson works about 2 500 000 ft. of water gas were made daily, from 10 000 to 12 000 gal. of Texas gas oil used daily and about 40 000 gal. of waste liquor passed into the river each day; also about 1 500 to 2 000 gal. of tar retained each day and burned under the boilers, one boiler being built to burn tar only, and two others tar that was sprayed or shot in on to the coal, as Mr. Safford has mentioned is now done at Lowell.

Mr. William E. McKay. — I have been greatly interested in Mr. Safford's paper. A number of years ago, at a gas works of which I was the engineer, the surplus tarry water from the manufacture of water gas had been allowed to flow into the adjacent salt-water bay. The small percentage of oily tar contained in the overflow water spread over the flats and emitted an unpleasant odor. At high tides this oily scum discolored the paint on the yachts sailing over the bay. To remove cause for complaint we provided a system for the repeated use of the same water in the manufacture of water gas; we installed a system of separating and settling tanks and a coke filter.

As a consequence of these changes the volume of water running to waste was reduced to 2 gallons per thousand cubic feet of gas made, and this waste water was entirely freed from tar or oil.

In the case of a gas works in Connecticut, where I was employed as consulting engineer, the plant was situated on the banks of a small river. In this case the tar from the manufacture of oil gas had been allowed to run into the river and this had resulted in many complaints and in several damage suits.

In this instance also we put in a system of separating the tar from the water by heating the liquid, and the waste water was finally filtered so that it was quite clean when it ran into the river. All cause for complaint was entirely removed.

In the case of the Boston Consolidated Gas Company, oil storage tanks are placed within concrete tanks and thus double provision is made against trouble from leaks. The proper disposition of drip water is to treat it as above described for tar water.

By providing a two-level overflow from gas-holder tanks it is possible to prevent the loss of oily water from an accidental blowing of the gas-holder.

In the matter of ammoniacal liquor, whether the solution is strong or weak, the waste of this liquor is a loss to the gas company, as ammonia is a valuable by-product, and except in the case of the very smallest gas companies no portion of the ammonia liquor should be allowed to run to waste either purposely or accidentally. At one of our stations we have recently built a storage tank for ammonia liquor 50 ft. in diameter by 21 ft. in height. This tank is built of reinforced concrete, and the floor and roof are reinforced concrete; when completed the entire interior of the tank was thoroughly coated with thick tar or thin pitch applied hot. This tank has been in use over a year and has

proved absolutely tight. The construction of ammonia storage tanks offers some difficulty because ammonia vapors rapidly corrode steel and iron. On the other hand, several expanded metal tanks built for the storage of ammonia liquor had not proved wholly satisfactory; we are disposed to believe that the waterproofing of the concrete with thin pitch is an element in this tank construction that has insured its success.

Mr. George Bowers. — You can imagine what my life was for five or ten years before Mr. Safford started on this problem. He has given you an intimation of the trouble in the newspaper clippings which he has read. The question was whether the Gas Company could be prevented from using the sewers or not. If we shut them off they would stop the gas business in Lowell and, of course, that would make trouble that we could not control, so we did not do it. I have a map of that part of the city which I will present to you as a diagram of this matter. This smell which is talked about, you would call a smell of gas; it has an odor like it, but it is not gas at all. It is what is called ammoniacal liquor, and people who have had it in their houses say it makes them sick. You wouldn't think much of it until you happened to get a whiff of it yourself. If you stood over a manhole when that odor came up everything inside you would come up as quick as lightning; you wouldn't have any time to think of it. Our superintendent of streets did not believe in this trouble until he stood over one of those manholes; then he went out of sight very quickly and had nothing more to say.

The Lowell Gas Light Company is situated at the corner of School Street and Western Avenue. All the drainage pipes from their works enter the sewer in School Street, which runs down School Street to Western Avenue, thence through Fletcher and Suffolk streets to Cross Street, a distance of about 4 000 ft., where the first trouble is located. Here are two or three houses where the people have been greatly troubled with this odor. From Cross Street the sewer continues down Suffolk Street to Moody Street, thence to Cabot Street, a distance of 2 000 ft. more, where we have the same trouble.

The Cross Street sewer is an 18-in. pipe sewer and falls about 3 ft. into the sewer in Suffolk Street. About 300 ft. from here our worst trouble is experienced. I have been called many times to the Lyons house, and have found the people at this place greatly agitated over the odor. The sewer connection here seems to be good; there is an iron trap in the cellar, and if you take the cover from the trap you will not get any gas smell

from it. There are houses connected with the sewer all the way from the gas works to this place, and the question is, Why does the trouble break out in these particular spots, so far removed from the gas works? None of these houses are located on the main sewers, but all are on branch sewers emptying into main sewers.

Mr. Weston. — There could not be a leak in it?

Mr. Bowers. — It would seem so, but how does the odor get there?

Mr. Weston. — Don't you get it from all the manholes all along?

Mr. Bowers. — You get it like this. It will come out here and there, and will skip a lot of them before it comes out. You will not find it right along; it will be in spots.

Mr. Farnham. — Do these houses stand any higher than the houses around them?

Mr. Bowers. — No. All along the street they are just the same. This particular house has it all the time. They get it first, and when it is bad it will go to the houses further along; and when it is very bad you get it in the street itself. It will come out of the manholes and people have to close their windows.

Mr. Farnham. — Do all of the houses in Lowell have a running trap for their connection?

Mr. Bowers. — Yes.

Mr. Adams. — What is the grade of the sewer directly below this Lyons house? I see it is on a branch sewer and not on the main.

Mr. Bowers. — About one in a hundred, and it has a fall of 3 ft. into the big sewer about 200 ft. from the Lyons house. It has manholes with large openings in the covers, and there is one about 100 ft. from the Lyons house, so that all gases should come out into the street before reaching this house. There is no reason why it should stay in the sewer until it came to the house. The Gas Company have scraped the snow and ice from the covers and kept them clean all the time, so that the gas should come out into the street and not be forced into the house.

Mr. Adams. — What is the foundation?

Mr. Bowers. — Ledge.

Mr. Adams. — It isn't in the ledge?

Mr. Bowers. — I don't think so.

Mr. Winslow. — Has this trouble occurred at any season of the year particularly?

Mr. Bowers. — It is worse when we have dull, heavy

weather; generally in the fall or in the spring when the snow is going off we have a good deal of trouble. When the concrete is washed in the gas-works yard you will find a little trace of oil in the sewer. Officials of the Gas Company deny that they allow any of this oil to enter the sewer. I have sometimes thought that it was due to the hot water which enters the sewer at several places. There are several large manufactories with steam plants, and they blow off their boilers into tanks and run a great deal of hot water into the sewers, which makes them look greasy and oily.

Mr. Barnum. — Mr. President, the gas companies in past years have let a good many liquids go into the sewer on which they could afford to spend a good deal of money in saving, which would bring them in a large return. One of these is the ammoniacal liquor. That is very easily retained by simply washing the gas with cold water, and letting all the liquor and the tar go into settling tanks, pumping off the liquor and the tar; there would be some water of condensation beyond the point where the ammonia is taken out, which would come on the top of a settling tank and that can go into the sewer and is perfectly good, provided the gas is properly cleaned before it reaches that point.

The waste from coal gas can be taken care of by engineering principles, simply by the expenditure of a reasonable amount of money for settling tanks. The trouble has come with sewers since water gas has been introduced. That is made from a crude oil, and the amount of oil and the proportion of oil and water and tar in the waste depend upon the character of oil and the temperature at which the gas is made. The tar being heavier than water, if the whole amount of waste is allowed to stand in settling tanks, the tar settles to the bottom and can be pumped off, and is worth about 4 cents a gallon as fuel. Where the trouble comes is in the oil; that has a most disagreeable odor, and is the odor that the gentleman from Lowell describes, and is a very difficult thing to remove, but it will yield to treatment such as Mr. Clark described.

The tar settles nicely and can be pumped, and as I say, the trouble comes in getting the oil off the top; that is what gives the very disagreeable odor, especially as the waste comes from the water gas at a temperature of 160 degrees and has to be cooled down. Then if any of this gets into the sewer and it should meet with any hot water or exhaust steam the trouble is more than abundant.

As for the place where the odor was noticed, I have had similar experience and found that there was some exhaust steam somewhere near that was heating it up; some local condition made it appear here or there, but the fundamental reason was that it was getting heated near that point somewhere.

The tanks that we have in Worcester to care for the coal gas are abundant and there is no trouble from that. For the water gas we put in a new system for separating and filtering. The liquor passes through eight tanks, 6 by 6 by 6, with large passageways between so as not to disturb and carry the settled tar along with it, and the liquid goes down from one tank underneath the baffle plate which extends within 18 in. of the bottom, and then up and over the next partition and through eight of these sections, 6 by 6 by 6 ft.

I have some samples here that I will show you. It is not stirred up now, but it is similar to what Mr. Safford showed you; what causes the trouble is the oil on the top. Here is the liquid that goes into the inlet of the settling tank. The liquid that comes out of the outlet of these eight tanks, which is the outlet of the settling tanks, comes like this. Now you will see that that has quite a little oil on top. The settling tanks will take out all but the oil on the top, and the coke will take out the oil, although a slight color will be left to the effluent due to the coke. Some color or film will come from perfectly clean coke.

THE CHAIRMAN.— Is that coke replenished from time to time?

MR. BARNUM. — That coke is replaced in the summer time about once a month and in the winter time about once a week, and being soaked with oil we take it to the boiler house and burn it. It makes a very cheap material for filtering.

These tanks are adaptable; they are quite flexible; you can increase their capacity. We have drain pipes from the settling tanks where the tar can be pumped off every day. The drain pipes in the coke basins also increase the capacity. I have run them as high as 150 gal. per minute. That sample was taken off at the rate of about 75 gal. I think, Mr. President, that is all I can say in regard to it. I would be very glad to answer any questions.

MR. BOWERS. — This business at Worcester is all done by the Worcester Gas Light Company, is it?

MR. BARNUM. — Yes. That is all done by the Gas Company. We built the tanks.

MR. BOWERS. — Did you have trouble there with the citizens making complaints?

Mr. Barnum. — Yes. Before we put in the new system our old tanks were made of wood and they leaked from section to section without following the proper course through, and they weren't large enough; when our make of gas was very large, that water would go in, looking very much like that second bottle, or even the third, and that would get into the sewer; there was a brewery across the way and the hot water from that brewery would get into the sewer and come in contact with this effluent, and when we had a south wind up through the valley that would take the odor up to the top of the hill about a quarter of a mile from the works, and then we would have complaints, and they were quite numerous.

Mr. Eddy.— There is one interesting thing in this connection which Mr. Barnum has not spoken of. It happens sometimes that the odors from the gas wastes are noticed by the citizens and something is causing the trouble which must continue.

For instance, in cleaning out the large surface water drain some time ago, which was a matter of a week or two, people would continue to get the odors throughout the time. I found by putting a curtain in the sewer on a wooden frame, made of cotton cloth or very light duck, it stopped the passage of the air current up the sewers, and furnished practical relief for several days. That may get you out of a scrape some time if you get into it.

Mr. Bowers. — Are the sewers and the manholes covered with oil?

Mr. Eddy. — Sometimes it is very thick, so thick that a man could not get into the sewer without getting covered with it. We have been cleaning out the sewers at the north end of the city above the gas works but below a local mill gas plant recently, and there the tar was up in the manhole to a good height where the water had carried it during high water, and not only was it on the sides of the manhole and on the sides of the sewer, but it had cemented the sand in the bottom of it; it had settled to the bottom of the sewer and made a thick paste of it, so it was very hard to clean out.

[Note.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1907, for publication in a subsequent number of the Journal.]

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STATE PROTECTION OF THE PURITY OF INLAND WATERS.

By R. WINTHROP PRATT, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Civil Engineers' Club of Cleveland, April 9, 1907.]

LAWS protecting the individual rights of riparian owners have been in force ever since the time of the Romans, and perhaps before that time. These laws are founded on the general principle that water, like air, is the common property of mankind, and that water flowing over the land is part of the realty and belongs to a certain extent to the owner of the soil. Such owner may take part of it for his own use, and may thus incidentally diminish its volume and perhaps alter its quality. But as the water naturally passes on to the owner of the adjoining soil, the next owner has precisely the same rights. It follows then, according to the above principle, that no riparian owner may appropriate all the water which comes to him, nor pollute, nor injure it so that the rights of other owners may be interfered with. In the past, the conflicting rights of different riparian owners have caused litigation in hundreds of instances.

It is impossible to define by law the exact extent to which the several riparian owners may use a stream. Generally speaking, however, the courts have decided that each one may make such use of the water for farming and domestic purposes as is reasonable, and the lower owners must expect the slight decrease in quantity and change in quality which necessarily follow such reasonable use. The question of what constitutes reasonable use must be determined in each case; but it has been

always understood that to discharge sewage, filth or deleterious waste material into a stream constitutes an unreasonable use.

The above is a general principle of common law and is independent of statutory provisions. This principle is of universal application, except in certain arid regions where the value and use of the land depend entirely upon the water supply. In such regions the principle of prior appropriation prevails, and this gives to certain owners the right to use the water from a stream to a specified extent — regardless of injury to owners below.

Necessity for State Supervision. — Common law has always afforded means by which private riparian owners injured by polluted streams can be heard in court, but the conditions of to-day demand more thorough means for protecting inland waters. The settlement of the country and the rapid growth of cities and towns have made necessary the use of certain streams for drainage purposes; and at the same time many municipalities are obliged to depend upon these same streams for their water supplies. Furthermore, to quote from a message of the governor of Pennsylvania, in 1905, to the legislature: "It is high time that attention be given to the preservation of our streams, gifts of God to humanity, which are essential to happiness and comfort and even to life. In Western Asia are vast lands where once were teeming civilizations, now barren wastes, because the people did not understand how to take care of their water supplies. Our streams are losing both beauty and utility, and are being encroached upon by filling along their banks, and using them as dumps for the refuse and pollution which comes from mills, factories and habitations."

These conditions clearly point to the necessity not only for specific statutory provision against stream pollution, but for supervision by some state or central authority whose duty is to investigate all matters relating to stream pollution and to see that sewage and other polluting substances are not allowed to enter in an unpurified state any stream or lake where a water supply would be endangered or where offensive conditions would result. By such arrangement much unnecessary litigation is avoided, and there are protected large numbers of persons, as well as municipalities, who, because of ignorance in sanitary matters, or because of the fear of becoming engaged in lawsuits, would fail to protect themselves. Through administrative control by the state, instead of adjustment through the courts alone, the future condition of our streams and water supplies can be

given much more weight; so that with the growth of the country, polluted streams will decrease instead of increasing in number.

Whenever the pollution of a stream or other body of water injuriously affects the health or materially interferes with the peace and comfort of a large but indefinite number of people in the neighborhood, such pollution is known as a public nuisance. But the public has, under these circumstances only, according to common law, the right to prevent the pollution of waters. When, however, there is a public ownership of the banks of a stream, as in the case of a source of water supply owned by a municipality, or a company which supplies the inhabitants of a municipality with water, then the public as a riparian owner is interested in the enforcement of the rights of such owners discussed above, and it is the duty of the public authorities to cause the abatement of any harmful pollution. The principles of common law under which municipal officials may cause such abatement are practically the same as those which apply to the individual riparian owner.

Unless specially forbidden to do so by statute, cities may use streams for the discharge of sewage and other filth; provided, that by so doing no injury is caused to the property down stream. If such injury is caused by a city to even a single riparian owner, then the city must properly compensate such owner or remove the pollution. This principle is well illustrated by the experience of the city of Columbus. This city, out of respect for the rights of a few farmers owning land along the Scioto River below town, is now spending $1 200 000 in extending the sewerage system and building purification works. It might be added that this respect for the rights of the farmers did not appeal strongly to the city authorities until the city has been compelled, after litigation, to pay heavy damages on account of polluting the river.

The above facts show that although common law affords a certain amount of protection, yet constant supervision by a state department, backed by statutory authority, is much more effective in securing the proper restriction of stream pollution, especially as regards the future growth of the country.

Status of Existing Legislation. — Countries and states in which the population is most dense seem to have given, out of necessity, the most thought toward preventing and regulating the pollution of streams.

Probably the most thickly-settled country, where first-class

sanitation exists, is England.* The total population of England is 30 800 000 and the area is 50 867 sq. miles; thus giving an average population of 606 per sq. mile. The population in the central part of England, or the county of Lancashire, is 4 437-500 and the area 2 030 sq. miles, thus giving a population of 2 190 persons per square mile. In order to compare this with American conditions a table has been prepared, showing the total population and population per square mile of several of our states.

State.	Population.	Area in Sq. M.	Population per Sq. M.
Massachussetts	2 420 982	8 315	291
Rhode Island	428 556	1 250	343
New York	7 268 012	49 170	148
Pennsylvania	6 302 115	45 215	139
Delaware	184 735	2 050	90
Ohio	4 157 545	41 060	101
Kansas	1 480 495	82 080	18

From inspection of the above table, it will be seen that the density of population in the central part of England is seven times that of Rhode Island, which is our most densely populated state, and twenty-one times that of Ohio. As another way of considering the density of population, it may be noted that there are in England practically as many cities of more than 50 000 inhabitants as there are in the United States; while the area of the United States is seventy-five times that of England.

Although the English Rivers Pollution Commission, established in 1868, performed valuable service in investigating methods of sewage disposal, the present English legislation regarding the prevention of the pollution of streams is based on the Public Health Act of 1875 and the Rivers Pollution Prevention Act of 1876. These acts prohibit the discharge of sewage, refuse and manufacturing waste into any stream where the purity and quality of the water would be affected thereby. A marked distinction is made, however, between cases where sewage was being discharged before the passage of the law and cases where the discharge has been commenced since that time. In the former case, the discharge of sewage was not deemed an offense, if it could be shown to the satisfaction of the court that the *best practical and available means* were being used to render the sewage harmless. It is said that this phrase, " the best practical and available means," has caused the act to become practically

* Mr. Geo. C. Whipple in Report on Sewage Disposal for City of Paterson, N. J.

inoperative, for the reason that the views of the various local authorities who are called upon to enforce the act vary so widely with reference to the definition of what constitutes the best practical means. Then by placing the enforcement of the act with the local officials it often happened that such officials were the greatest offenders in regard to the pollution of streams and were consequently not enthusiastic in regard to improving conditions.

A distinct advance was made in 1888 by the enactment of a law which placed the enforcement of the Rivers Pollution Act with the county authorities; and which gives to the Local Government Board (a national body) power to appoint joint committees representing the interests affected and investing them with ample power.

One of the most important committees appointed by the Local Government Board is the Joint Committee for the Mersey and Irwell Watersheds, established in 1892. The West Riding of Yorkshire Committee, another important one, was appointed in 1894. These committees were directed and empowered to enforce certain laws regarding the pollution of streams, and they were given ample authority to study all problems regarding the purification of sewage. The territory under the jurisdiction of these two committees is 4 800 sq. miles, and the population affected is 5 200 000. The acts of these committees must be approved by the Local Government Board, which board, as is well-known, must approve the expenditure of all money by municipalities.

As a practical illustration of the work done by the Yorkshire Joint Committee, it may be mentioned that in 1892 there were but thirty-two municipal sewage works in operation, whereas there were in 1904 eighty-five under the committee's charge.

In 1898 there was established a royal commission on sewage disposal, whose function it is to study in detail all methods of purification, with reference to advising the Local Government Board and other authorities. The final report of this commission has not yet been issued, but it is expected that this report will appear during the coming summer. Its publication is looked forward to with much interest by sanitarians all over the world.

The Constitution of the United States contains no provision which gives to Congress, generally speaking, the jurisdiction over the pollution of waters of this country. This condition

exists, no doubt, because at the time the Constitution was adopted the great importance of the subject from an interstate point of view was not thought of; hence, by the principle of state rights, each state has full power to regulate pollution of streams except where such powers are restricted by the national Constitution, or especially delegated to the national government.

Under these circumstances, uniformity of legislation in the various states is not to be expected. The natural conditions in different parts of the country are so various, the density of population and the public intelligence as to the deleterious effects of water pollution vary so widely, that the statutory regulation must necessarily differ. Those states which are most advanced in the matter of sanitation have become so through placing the control of stream pollution in the hands of some state department whose special duty it is to look after this matter.

In a paper by Mr. Edwin B. Goodell, published in 1905 by the United States Geological Survey, the states and territories are grouped into three classes: First, those having partial statutory restrictions against stream pollution; second, those having general statutory restrictions; and third, those having severe statutory restrictions.

Class I. — States with partial restrictions:

Alabama, Arkansas, Delaware, Florida, Georgia, Idaho, Iowa, Kentucky, Michigan, Mississippi, Montana, Nebraska, Nevada, North Dakota, Oklahoma, Rhode Island and Wisconsin.

In this class are found states where there is nothing more than a simple provision making it a crime to poison wells and springs. There is manifest in their legislation no sense of the general desirability of protecting public water supplies, but rather a desire to guard against certain criminal acts which would injure special groups of persons whom the legislature desires to protect.

Class II. — States with general restrictions:

California, Colorado, Illinois, Indiana, Louisiana,* Maine, Maryland, Missouri, New Mexico, North Carolina, Ohio, Oregon, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia and Wyoming.

In this class are those states and territories whose legislatures recognize the necessity of pure drinking water for every inhabitant. These laws are general in their application, and vary much as to the remedies and penalties provided; but in every case it is clearly set forth that all streams and water

* Legislation passed in 1906 places Louisiana in this class.

supplies are to be carefully protected, and the penalty for breaking the law is by no means insignificant. For instance, the Ohio statute, which is representative of this class, says: "Whoever . . . corrupts or renders unwholesome or impure, any watercourse, stream or water . . . shall be fined not more than $500."

Class III. — States with severe restrictions:

Connecticut, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania and Vermont.

The third class might be included under Class II, but it is distinguished from Class II by the fact that the states have adopted, in addition to the general laws, more definite and stringent laws to enforce the right of their citizens to unpolluted waters. These states all have active health departments specially authorized to act as guardians of the streams and to control matters relating to water supply and sewerage. Laws representative of this class will be discussed below in connection with the work of the state health departments.

In considering these three classes, it should be borne in mind that the states with the most stringent laws are not necessarily the most effective in securing pure water supplies and unpolluted streams. In order to obtain best results, the public and especially the local officials must be so educated that they will realize the importance of proper sanitation. It is more essential that a state board of health or other supervising body have funds and assistance enough to keep in touch with all local conditions within its jurisdiction, so that it can properly advise and coöperate with the local officials, than that the statute books be loaded with stringent health laws with nobody to intelligently enforce them. There are always some cases, however, where nothing but the enforcement of strict laws would be effective.

It will be noted from the above discussion, that public opinion, in both this country and abroad, is steadily progressing in the enactment of laws to enforce the rights of riparian owners and to protect the public health.

Work of the State Health Departments in the United States.

All the states in the Union, with the exception of one, Idaho, have state health departments or state boards of health. The first state to establish such a board was Louisiana in 1855. Massachusetts followed in 1869. In passing, it is interesting to note that although the Louisiana state board of

health was the first board created, the legislature of that state failed until 1906, fifty-one years later, to pass any laws for the protection of public water supplies.

The duties of the state boards of health were at first principally advisory; but in recent years legislatures have granted more authority, so that most state boards now have abundant executive powers in matters relating to quarantine, contagious diseases, and the disposal of dead bodies. A comparatively small percentage of them, however, has much authority in regard to, or are active in, the work of protecting the purity of public water supplies; although each year more attention is being given to this important feature of state health work.

The eight states listed above, under Class III, together with Indiana and Ohio, are probably at present doing the most work in this respect. Very few of these ten state boards of health, however, have power to change existing conditions when this means any considerable expenditure on the part of a municipality or water company; but all of them have power to control the increase of pollution. I will discuss briefly the work of some of those boards which are giving the most attention to matters relating to the protection of water supplies and the purification of sewage.

Massachusetts. — Massachusetts is considered the pioneer among states in her work of protecting the purity of inland waters. As long ago as 1878 an act was passed making it unlawful to discharge sewage or other polluting material into any stream used for a public water supply, within 20 miles above the location of the intake. The old theory of the "self-purification of streams" was apparently the reason for assuming that 20 miles would be a safe distance. The state board of health, founded in 1869, was reorganized in 1886, and during the next few years laws were passed, giving to this board general supervision over all public water supplies, directing all local officials to ask its advice before carrying out any proposed water supply or sewerage plan, and in addition, giving it power to remove any source of pollution within 100 feet of the high-water mark of any stream or pond used as a public water supply. These laws were later amended so as to give the state board of health, upon request from the city or town, power to make rules and regulations governing the entire watershed above any water supply intake. Provision for enforcing these rules and regulations was also made. Exceptions, however, were made in the cases of the watersheds of the Merrimac and Connecticut rivers

and of so much of the Concord River watershed as lies within the city of Lowell. Streams under control of the Metropolitan Water Board were also exempted from the jurisdiction of the state board of health.

The great success of the Massachusetts state board of health has been due in a large measure to the fact that it has been empowered, from the beginning, to make extended experiments and investigations, and has thereby accumulated a great fund of information relating to local problems. As mentioned above, the law simply requires cities and towns to ask the advice of the board, but does not require them to follow it. The fact that this advice almost always is followed, however, indicates that the work of the board has been appreciated. Thus when it became necessary to make extended investigations for the Metropolitan Water Supply District, consisting of Boston and surrounding cities, the state board of health was given direction of the investigations and the work was accomplished more thoroughly and more quickly than a temporary commisson could possibly have done it. The same is true of many other special investigations which the legislature has from time to time ordered the board to make.

One of the most prominent features of the work of this board has been the experiments upon purification of water and sewage, which have been conducted at the Lawrence Experiment Station during the past twenty years. The reports upon these experiments are now regarded as classics on sewage disposal, being constantly referred to and quoted by engineers in this country and abroad.

In certain instances, notably in the case of the Neponset River watershed, the legislature has given to the Massachusetts state board of health absolute jurisdiction in removing such sources of pollution as rendered the stream offensive, regardless of whether or not a public water supply was involved. As the pollution of the Neponset River consisted principally of manufacturing wastes, the abatement of this pollution necessitated careful studies, on the part of the state board of health, with reference to the best means of purifying these wastes without undue expense to the manufacturer. Studies of the purification of paper mill waste, tannery waste, woolen mill waste, silk mill waste, ink works refuse, and other wastes, have therefore been made; and the results of these are of great value, not only to the state of Massachusetts but to all other states.

In connection with removing gross pollution from rivers, the

board has made careful inquiry into the relative proportion of sewage and stream flow which may obtain without causing a nuisance. The general conditions, including the population, on the watersheds of some twenty-seven rivers were carefully studied; and frequent chemical analyses as well as inspections were made, for a period of two or three years, of the river water. Upon tabulating results, it was found that it is necessary, in order to avoid rendering streams offensive to sight and smell, that the flow of any given river amount to at least $3\frac{1}{2}$ cubic feet per second for each 1 000 persons discharging sewage therein; and that in some cases a flow of 6 cubic feet per second per 1 000 persons discharging sewage was necessary in order to avoid a nuisance.

For over twenty years, therefore, the Massachusetts state board of health has been keeping a constant supervision of all existing water supplies, conducting experiments and investigations on water and sewage purification, advising local officials with reference to their problems, and abating to a large extent the gross pollution of certain rivers. This admirable sanitary work has been rewarded by a distinct improvement in the public health, as indicated by the low average of the typhoid rates in the cities of Massachusetts during the last ten years. This rate is only about 20 per hundred thousand, which is but one-third or one-fourth of the average rate for the cities of Ohio or Pennsylvania. Almost without exception, the water supplies of Massachusetts are safe, and a stranger within the boundaries of the state need have little fear of drinking impure water.

New York. — In 1901 the state board of health of New York was discontinued and a health department under the direction of a health commissioner was established in its place. The health commissioner is appointed by the governor for a term of four years. He has full charge of the work and organization of the department. As at present organized, the department consists of a division of sanitary engineering, division of laboratory work, division of vital statistics, division of communicable diseases, and division of publicity and education. This organization has been in force for two years and promises to accomplish very effective results.

All plans for proposed sewerage and sewage disposal must be approved by the health department before being carried out; and this department may impose such conditions regulating the discharge of sewage, as well as manufacturing wastes, as it deems proper.

As yet there is no law in New York which makes it necessary that all proposed plans for water works be approved, although there has been in force for nearly twenty years a law by which the state health department (or formerly the state board of health) is required to make rules and regulations for the protection of the watersheds of streams used for domestic purposes. Ample provision is also made for enforcing these rules and regulations, even though in carrying them out it necessitates building sewage purification plants. Every local water works official is required to make such inspection of the watershed as the state health department may direct.

Pennsylvania. — Two years ago the legislature of Pennsylvania created a state health department to supersede the former state board of health. This new department, similarly to New York, is under the supervision of the commissioner of health. The powers conferred upon the department are very great, not only as regards the general work in controlling infectious diseases and in keeping vital statistics, but especially as regards the control of water supply and sewerage problems. It is probable that no legislature at a single session ever enacted such sweeping health measures and appropriated so much money ($350 000) to carry them out.

A very important part of the department of health is a division of engineering, the special function of which is to carry out the provisions of an "Act to Preserve the Purity of the Waters of the State for the Protection of the Public Health." Under this law, every municipal or private corporation is obliged to file with the department of health, certified copies of complete plans, surveys and description of the water works under its charge. No new water supply can be placed in use and no addition can be made to an existing supply without a written permit from the commissioner of health.

In a similar manner, all municipalities are required to file with the department of health, plans and information concerning sewerage systems and sewer outlets. No sewage can be discharged into any stream without a permit from the commissioner of health, through any sewerage system which has been extended since the passage of the act (1905).

As nearly every municipality is called upon to make sewer extensions every year, it is clear that all sewer outlets in the state will soon be under control of the health department. The permit of the commissioner of health can be revoked whenever it is considered that there are being created conditions

injurious to the public health. This makes it possible for the health department to require the sewage of any municipality to be purified when necessary. This law also applies to manufacturing wastes, except drainage from coal mines and tanneries.

Vermont. — The powers of the state board of health of Vermont are similar to those of Massachusetts and New York in regard to the making of rules and regulations protecting water supplies; and they are also similar to those of Massachusetts in that all local officials and manufacturers are required to consult the state board of health before adopting any system of water supply or sewerage.

There is one important feature of the Vermont law, however, which in a way places it in advance of any other state. This is the law which gives to the state board of health authority " to prohibit any town, city, village, public institution, individual or water or ice company from using water or ice from any given source whenever in its opinion the same is so contaminated, unwholesome and impure that the use thereof endangers the public health. And the court of chancery shall have jurisdiction and power, upon application therefor by the state board of health, to enforce by proper order and decree any order, rule or regulation which said board may make under and by virtue of this section."

This law, although passed only three years ago, has already been enforced by the state board of health in the cases of four or five cities, including the city of Burlington, where the water was shut off from all public fountains and public buildings, with the consequence that the citizens soon arranged to build a filtration plant.

Ohio. — Although Mr. Goodell's classification places Ohio in the second class, *i.e.*, with states having only general laws for the protection of water supplies, yet these general laws have been used to advantage, and consequently Ohio is considered by sanitarians all over the country as distinctly a leading state in public health work, including the protection of water supplies and the purification of sewage.

The Ohio state board of health was created in 1886. The board was given the usual general powers regarding the control of epidemics and infectious diseases. It was also given advisory powers regarding public water supplies and sewerage; but had no absolute authority over these. The board is composed of seven members, one being appointed by the governor each year.

In 1893, at the time of the cholera epidemic at Hamburg,

when some cholera cases were being imported into this country, the Ohio legislature realized the importance of protecting public water supplies, and therefore increased the authority of the state board of health along these lines. The present law, as passed in 1893, reads as follows: "It [the state board of health] shall respond promptly, when called upon by the state or local governments and municipal or township boards of health, to investigate and report upon the water supply, sewerage, disposal of excreta, heating, plumbing or ventilation of any place or public building; and no city, village, corporation or person shall introduce a public water supply or system of sewerage, or change or extend any public water supply or outlet of any system of sewerage now in use, unless the proposed source of such water supply or outlet for such sewerage system shall have been submitted to and received the approval of the state board of health."

Since 1893, therefore, it has been necessary that all plans for new projects for public water supplies or sewerage be approved by the board. In regard to works in existence previous to 1893, the board has no jurisdiction except to investigate and point out to local officials any conditions which need improvement. This lack of control over existing works is a weak point in the present sanitary laws of the state and is the feature which prevents Ohio from being placed in the same class (as regards stringent legislation) with such states as Massachusetts, Vermont and Pennsylvania. It is expected, however, that the present legislature at its next session will strengthen the existing law.

In 1898 legislation was enacted, authorizing the state board of health to establish and maintain a laboratory for the chemical and bacteriological examination of public water supplies and of sewage effluents; in addition, pathological work was provided for. The board was directed to annually examine and report upon the condition of public water supplies.

About this time the board also established an engineering department for the purpose of making careful investigations of the proposed water supply and sewerage projects which came before it for consideration, as well as for studying the conditions of existing works.

During the years 1897 to 1902, inclusive, the board has, through its engineering department laboratory, and with the aid of other temporary expert assistance, made a detailed study of the watersheds of all the principal rivers in the state. One or two watersheds were taken up each season. These studies included an investigation of all sources of pollution both from

cities and villages, as well as from factories. All sewerage systems and water works were examined in detail, and the population using such works was determined. Chemical analyses of the rivers themselves were made at regular intervals, and the pollution of the water, in many instances, was thereby conclusively demonstrated. The results of these investigations, including maps and statistical information, will be found in the annual reports of the state board of health. These reports afford a very comprehensive view of Ohio conditions as regards stream pollution.

Supplementary to the above work, stream gaging stations were established on certain rivers; and these were later maintained for several years by the United States Geological Survey, under the immediate direction of the engineer of the state board of health. Daily gage readings and records of discharge, covering periods of from six months to three years, of some fifteen of the rivers of Ohio are now available. These have been of great service in studying sewerage problems and also in other work.

During 1905 the board, acting coöperatively with the Hydro-Economic Division of the United States Geological Survey, made a detailed study of the disposal of certain industrial wastes which had long been sources of complaint. Much valuable and practical information was gained in regard to the purification of dairy refuse, woolen mill waste, acid iron waste from tube works, and the refuse from distilleries. The work on this last was especially interesting, as a method was developed whereby the valuable ingredients in the refuse could be reclaimed at a very substantial profit to the distiller. The owners of the distillery at Lynchburg, Ohio, instead of spending money to defend themselves against law suits for stream pollution, now have an income from the sale of their treated refuse.

In 1906, on account of the increased responsibilities of the board, due to the many important projects for water supply and sewerage which were submitted to it for approval, the legislature made a special appropriation to enable it to increase its engineering and laboratory force sufficiently to make a detailed examination of the construction, methods of operation and efficiency of all existing water and sewage purification works in the state.

At the present time, therefore, the Ohio state board of health is giving a great deal of attention to the problems of water supply and sewage disposal. The routine work of the engineering department consists in making reports upon the

proposed schemes which are continually being submitted, in responding to the calls of local officials for advice, in inspecting the construction of new work in order to see that it is being carried out in accordance with the approved plans, and in making, as far as possible, regular examinations of existing water supplies.

The special work consists of a series of detailed inspections of the water purification and the sewage purification works in operation in this state. One of the assistant engineers devotes his entire time to the water purification works and another to the sewage purification works. Each visit usually occupies two or three days during which, in case of water purification works, samples of raw and of filtered water are collected, for analysis, at frequent intervals; and observations of the rates of filtration, coagulants used, and of other features are carefully made. The bacterial samples are all plated, and most of the other analytical work is done, at the plant. This avoids the undesirable feature of shipping the samples by express. A corresponding procedure is followed in the inspection of sewage plants.

This water and sewage work has proved of very great value, not only on account of the information which the board has gained for use in acting upon future plans, but also because the work has served generally to educate and interest local officials in their own plants. In a few cases the plants have been materially changed, on the strength of the board's recommendations, and their efficiency greatly increased. At four of the larger sewage plants, the operators have been trained to make each day simple chemical and incubation tests of the purity of the effluents. At both the sewage and water plants, in the majority of instances, the superintendents are furnishing the board with daily records of the principal features of operation.

The importance of water filtration to the people of Ohio is very great. The difficulty of obtaining abundant ground water supplies makes it necessary for all of our large towns and cities to depend upon surface waters, which in nearly every case require filtration, either because of sewage contamination or because of turbidity or for both reasons. At present, in Ohio, water filtration plants are in operation in fourteen municipalities, having an aggregate population of 175 000 people. Within a year, plants at Cincinnati, Columbus and Toledo will be completed; and then the above figure will be increased to over a million people. Ohio will then lead all other states, excepting possibly Pennsylvania, in the per cent. of her population served with filtered water.

The small dry-weather flow of most Ohio streams and the

building up of communities along their banks, have made the problem of sewage disposal an important one in this state. At present there are 35 sewage purification plants in operation in Ohio. Nineteen of these are municipal plants and 16 institutional. Plans for some 30 more have been acted upon by the state board of health and some of these are now in process of construction. By far the largest plant in the state is the one now being built at Columbus. When this is done the total population in Ohio tributary to sewage purification works will be nearly 300 000.

One of the most important problems with which the board has to deal is the question of the degree to which a given sewage must be purified. There are many factors which affect this question. A single standard of purity applicable to all cases is not tenable. In cases where it is not necessary to protect a water supply, or dairy, shell-fish or market garden interests, there is obviously no need of purification greater than that obtained by removing most of the suspended solid matter and rendering the liquid, together with the small amount of solid matter which may remain in it, non-putrescible; that is, the purified sewage must be fairly clear and must not putrefy and become offensive on standing indefinitely at as high a temperature as 98 degrees fahr.

Where the stream receiving the effluent is used for public water supply purposes, the problem takes on an economic aspect and the question arises: Ought a municipality to be required to increase the cost of its sewage works, say two or three times, and transform its sewage into a potable water for the purpose of protecting a water supply many miles down the stream, when the stream through its numerous tributaries undoubtedly receives a greater or less amount of miscellaneous pollution before reaching the water supply intake? Ought not all dangerous organisms which may come from the sewage works or from elsewhere on the watershed to be removed by water filtration works operated by the municipality or company owning the water works? Especially is the last question significant if water filtration works are already in operation.

It is necessary to carefully weigh the conditions governing each case in order to arrive at a just decision. There are natural agencies of purification in every stream; but so far as the removal of dangerous bacteria is concerned the value of these agencies is uncertain. This is on account of constant fluctuation in the velocity and volume of stream flow, changes in temperature, changes in chemical and physical composition of the water, and

other factors. According to the official statement of the Rivers Pollution Commission in England in 1868, "There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source." Subsequent experience in England, as well as in this country, has to a large extent borne out the significance of this statement. Swift-running rivers, contrary to the usually accepted theory, are more dangerous than sluggish streams in regard to conveying pollution; for with the latter, pathogenic organisms are longer subjected to "unfavorable environment." Dilution is an important factor in purifying a stream, but cannot be counted upon to remove all harmful matter of sewage origin.

All things considered, it seems unjust to allow a community to discharge into a stream used as a water supply any disease producing organisms, the destruction of which can be effected without unreasonable difficulty; provided, of course, that the sewage works are located at such a distance from the water supply that the natural agencies above discussed cannot be depended upon. In other words, the water filtration works should not be given an extra burden to perform. This is especially true under the usual American conditions, where the care of water filters is often intrusted to careless or incompetent management. Water-works officials, whether they operate a filtration plant or not, have a right to expect that as much pollution as possible be kept out of the sources of supply, at every point; and that the water be as pure as is practicable to make it before arriving at the intake. "Innocence is better than repentance."

To purify sewage to the high degree above discussed means considerable added expense. Either sand filters of ample area must be installed for the final treatment of the sewage effluent, or there must be provided some means for disinfecting with chemicals the effluent from works which only purify the sewage to the non-putrescible state.

The Ohio state board of health has required sand filters to be added to proposed works in several instances where the effluent was to be discharged into a stream used as a water supply. The practicability and efficiency of the disinfecting process, however, is one of the most recent developments in the art of sewage purification, and it is not yet definitely settled whether this method will be practicable under all conditions. It is reported to have been used in England at several places with

good results. Chlorine, or its compounds, seems to have afforded the best and most economical results. This substance can be produced electrolytically from salt water at small expense.

By way of coöperation in working out this problem, the Bureau of Plant Industry United States Department of Agriculture, has for the last eight months placed at the service of the Ohio state board of health two bacteriologists; and under the direction of the board these men have been making thorough tests of the treatment of effluents from different sewage purification plants, with both sulphate of copper and chloride of lime or bleaching powder, which when decomposed produces chlorine.

One of the most important series of tests has been made at Marion, Ohio, where the effluent from the sewage works is discharged into the Scioto River, forty-five miles above the Columbus water supply intake. It is believed from the information recently gained in these experiments, that a sewage effluent can be freed from pathological organisms without undue difficulty and expense. This process will be a great protection to water supplies in the future, especially at times of epidemics.

The complete report upon the special investigation of the board into water and sewage purification, including the disinfection of sewage effluents and the softening of water, will be published about a year hence.

Recent Agitation on the Part of the Engineering Societies of Ohio for the Prevention of Stream Pollution.

Before closing, I wish to call attention for a minute to the recent movement, among the engineering societies of Ohio, in regard to future protection of the streams of this state and also of Lake Erie. On May 11, 1906, representatives of the Ohio Engineering Society and the Engineers' Clubs of Cleveland, Cincinnati, Toledo and Columbus, respectively, met at Columbus to consider matters relative to the pollution of public water supplies. Organization was effected and the committee was called the "Joint Committee of the Engineering Societies of Ohio for the Prevention of Stream Pollution." Mr. Walter E. Rice, a member of your society, was elected chairman, and the speaker, secretary. Sub-committees were appointed as follows: Committee on legislation: committee on ways, means and scope; and committee on statistics. Each of these sub-committees is to make a report at the next meeting of the Joint Committee, and a general procedure will be decided upon for obtaining legislation in this state and in other states bordering the Great Lakes, for protecting the purity of inland waters.

DISCUSSION.

Mr. A. Elliott Kimberly. — From Mr. Pratt's clear presentation of the subject of the protection of water supplies, it is apparent that the question of their control should rightfully be invested in a central or state authority, clothed with laws giving administrative as well as advisory power. Under these conditions it justly may be asked, To what extent shall such authorities carry demands for water supply protection? What shall be the limit of sewage purification required, in cases where the sewage problem of one city is correlated to that of the water purification problem of an adjacent city?

Leaving the question open to be decided more properly perhaps by local conditions, as suggested by Mr. Pratt, there arises the thought as to the degree of purification to which sewage can be subjected in a practical way in the light of present information. Since the removal of the offensiveness of sewage has long since reached a state of practical accomplishment, developments well known from the construction and operation of purification plants on a practical scale, as a further step in advance there suggests itself the feature of producing an effluent of bacterial as well as of chemical purity. This phase of the question, as Mr. Pratt states, has been discussed considerably abroad, but American tendencies in this regard are of more recent date. Information as to the disinfection of sewage effluents in this country is probably confined to experiences with copper sulphate treatment at Vineland, N. J. (1905),* to laboratory experiments carried out at Columbus, Ohio (1906),† and to a study of sewage effluent disinfection carried out on a laboratory scale by Phelps and Carpenter at Boston (1906).‡ Some work along this line, particularly the use of chloride of lime or bleaching powder, was suggested by Phelps for the treatment of the effluent from a septic tank at Redbank, N. J. (1906).§

In the latter part of 1906 there was begun in Ohio a study of the disinfection of sewage effluents on a practical scale under

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* Newcomb, Edwin L.: New England Water Works Association, December, 1905, Copper Sulphate Symposium.

† Johnson, G. A., and Copeland, W. R.: "Copper Sulphate as a Germicide." *Journal of Infectious Diseases*, I, Supplement No. 1, p. 327.

Johnson, G. A.: Report on Sewage Purification, Columbus, Ohio, 1905, pp. 471–479.

‡ Phelps, Earl B., and Carpenter, W. T.: *Technology Quarterly*, XIX, No. 4, p. 382, December, 1906.

§ State Sewerage Commission, New Jersey, Report 1907, p. 252.

a coöperative agreement between the United States Department of Agriculture, Bureau of Plant Industry, and the Ohio State Board of Health. These experiments were probably the first to be carried out in this country on the disinfection of sewage on a scale comparable to practical requirements. The work embodied a study of the practicability of disinfecting comparatively large volumes of sewage effluents with the use of copper sulphate and chloride of lime or bleaching powder. The problem was studied at Westerville, Ohio; Lancaster Boys' Industrial School, a state institution near Lancaster; and at Marion, Ohio.

As a preliminary to the studies at each of the above stations, facilities were provided for the control of the application of the disinfectant, for the continuous measurement of the effluent flow and for a certain storage period of the treated effluent. The actual experiments included full bacterial and chemical analyses of composite and average samples collected throughout the period of a test, the greater part of the work being carried out in the field with the aid of a portable laboratory.

As disinfectants, both copper sulphate and chloride of lime were studied, the former in extension of the Bureau of Plant Industry's algæcidal work, and the latter, a development from current thought in England, from German practice and from suggestions from Phelps and Carpenter's experiments at Boston on sewage effluent disinfection. For a detailed account of these tests, reference should be made to Bulletin 115 of the United States Department of Agriculture, Bureau of Plant Industry, and also to the forthcoming report of the Ohio State Board of Health's special investigations of water and sewage purification plants. Suffice it here briefly to refer to some of the interesting indications brought out by the experiments, as suggesting that the protection of water supplies from sewage effluents is a problem of much practical possibility even for continuous treatment, and assuredly for emergency use in times of epidemics.

The data obtained were average results from the treatment of the entire volume of sewage flow during the period of disinfection, which was continued for from six to eight consecutive hours at each run. The following table shows the quantity and the kind of sewage treated at the different plants:

Summarized Statistics of Disinfectant Experiments.

Station.	Number of Runs. Copper Sulphate.	Chlorine.	Duration of Test (Hours).	Kind of Effluent Treated.	Rate of Flow, Gallons in 24 Hours.
Westerville.........	16	–	8	Continuous contact.*	41 000
Lancaster..........	10	3	8	Intermittent sand.	160 000
Marion............	9	3	6	Subsidiary sand.	600 000
Marion............	1	3	6	Contact.	600 000
Marion............	–	9	6	Septic tank.	600 000

*Contact filters of cinders operated on continuous basis, outlet open. Surface not submerged.

As discussed in Bulletin 115, very satisfactory results were obtained with both copper sulphate and chloride of lime. Copper sulphate appeared the more limited as regards its adaptability to practical conditions, in that its efficiency is perhaps more dependent upon a high-grade sewage effluent, together with a required storage period of at least 3 hours; chlorine, as bleaching powder, on the other hand, requires less storage and is less susceptible to organic matter.

The indications drawn from these studies were, briefly, that a sewage effluent (Lancaster, 160 000 gal. daily) of a purity equal to that from efficiently operated intermittent sand filters may be disinfected as regards B. coli by the use of 13 parts per million of copper sulphate (109 lb. per million gallons) with a storage of treated effluent of about 3 hours and at a cost for chemical of about $6.54 per million gallons. Similar results with chloride of lime required about 4 parts per million available chlorine (134 lb. per million gallons bleaching powder containing 25 per cent. available chlorine), under one hour's storage and at a cost of $3.35 per million gallons.

With less highly purified effluents, greater amounts of copper sulphate were required, 40 parts per million (334 lb. per million gallons) applied to the Westerville continuous contact filter effluent (41 000 gal. daily) removing, however, about 99.3 per cent. of the acid-forming colonies under about one hour's storage and at a cost for chemicals of about $20 per million gallons. Chloride of lime, on the other hand, under the application of lesser amounts, appeared to be quite efficient for effluents of less stability than those from sand filters, results from the putrescible Marion contact filters showing a removal of 100 per cent. of fermenting organisms with the use of 5 parts per million of applied chlorine (167 lb. per million gallons bleaching powder containing 25 per cent. available chlorine), at a cost for chemicals of $4.17 per million gallons.

Passing to septic tank effluents (Marion), the use of as high as 25 parts per million available chlorine (835 lb. per million gallons bleaching powder containing 25 per cent available chlorine), at a cost for chemicals of $20.87 per million gallons, removed 99.3 per cent. of fermenting organisms, indications being strong that a more thorough settling of the septic effluent and the application of larger amounts of chemical would effectively destroy organisms of the B. coli type. The increased cost would, of course, be admissible in cases of epidemics, and moreover, only under such conditions would there probably ever arise the question of the treatment of a sewage effluent as putrescible and as difficult to disinfect as the effluent from a septic tank.

The idea of the occasional disinfection of sewage effluents appears to have assumed a more definite shape abroad, especially in England, where, as summarized by Rideal,* experiments have been carried on at a number of places, notably at Maiden Head, Hertford and Guilford. Some work has also been done in India,† where chloride of lime has been used for disinfecting the effluents of septic tanks. In Germany, particularly, disinfection has for some time been considered practical as a remedial measure in the case of epidemics and for continuous treatment for the sewage of hospitals. In Schmidtmann and Gunther's report on bacterial purification of sewage in Germany,‡ from data there published, it appears that out of the 18 principal plants in Germany, 8, or 44 per cent., have permanent facilities for occasional disinfection. German conditions, of course, refer to much stronger sewages than those in America, and consequently figures as to the quantity and the cost of disinfection far exceed those probably necessary in this country. Thus Schumacher's § conclusions are quoted in the above-cited report, stating that for raw hospital sewage there is required chloride of lime 1: 2000 (average available chlorine 167 parts per million) under a two hours' contact; other experiments show complete disinfection at a chloride of lime concentration of 1: 5000 (average available chlorine, 67 parts per million). As a lower limit, the quantity of available chlorine is placed for well-purified sewage effluents

* Rideal, Samuel: "Sewage." Third edition, 1906, pp. 179–192.

† Indian Government: "Resolutions on the Workings of Septic Tanks." Calcutta, January 6, 1906.

‡ Heft VII, "Mitteilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung und Abwässerbeseitigung, 1906."

§ "Die Desinfektion von Krankenhausgruben mit besonderer Berücksichtigung des Chlorkalkes und ihre Kontrolle." *Ges. Ingenieur.*, 28 Jahrg., 1905, pp. 361–368, 377–384, 393–397.

at 1 : 60 000, or about 17 parts per million. Information appears to be almost as indefinite in Germany as in this country, although the recent Ohio experiments have probably suggested more nearly the probable practical limitations of the use of disinfectants in relation to sewage effluents of different degrees of organic purity.

Speaking generally, it does not seem too extreme to interpret available information as regards the disinfection of sewage effluents as indicating the practicability of producing an effluent of bacterial as well as of chemical purity, the former as a remedial measure for the protection of water supplies in epidemical outbreaks, and both as an all-the-year requirement for special cases of closely related water and sewage purification plants. However great may be the advance in knowledge as to practical disinfection of sewage effluents, actual and lasting benefit will probably be assured only when central or state authorities shall have complete and final control of water supplies by powers vested in them by the legislature of the state.

Mr. Wm. S. Johnson. — The subject of Mr. Pratt's paper is of special interest to the writer since he has recently been connected with two cases in Massachusetts, where the advantages of state control of the purity of inland waters have been forcibly impressed upon him. In Massachusetts the state exercises a certain control over inland waters through its board of health, and it has sometimes been claimed that this control is so burdensome as to be an injury to manufacturers and to the state as a whole. The two cases referred to, however, indicate that better results will be secured by such control than by the ordinary process of law.

The first of the two cases is one in which a manufacturer located on a certain stream brought suit against a city which discharged sewage into the stream above the factory. The action was brought several years ago and the manufacturer has spent large sums of money in obtaining evidence and preparing the case. The city which discharges the sewage into the stream prepared to fight the case and spent still larger sums. The stream is one of the most foully polluted in Massachusetts, and no one could possibly deny that the concern which brought suit, as well as any other corporation or individual located near the stream, was injuriously affected by the foul condition of the water. The case was somewhat complicated by the fact that the stream received manufacturing wastes as well as city sewage, but the quantity of the city sewage was alone sufficient to create a

decided nuisance. The officials of the city openly stated that it was cheaper to pay considerable sums of money each year in fighting the case in the courts than to pay the cost of maintenance of expensive sewage purification works. After the case had dragged along for several years, never coming to a trial, it was withdrawn by the complainants, apparently because of certain technicalities or legal obstacles, although the case seemed, from an engineering standpoint, to be a perfectly clear one. This is a case which should have been considered by some properly constituted authority, either capable of determining the facts for itself, or empowered to employ competent experts, and without the necessity of the great expenditure of money by those affected.

The second case was brought by the owner of a small mill which had previously been used for the manufacture of paper. Some time after the shutting down of the mill, suit was brought against a large manufacturing corporation which operated a woolen mill a short distance above the paper mill. This matter has been in the courts for about five years, and recently the full bench of the Supreme Court rendered a decision ordering that an injunction be issued restraining the woolen mill from the further pollution of the stream. The question of damages is still unsettled and is now before a master.

This also is a case which has cost enormous sums and which could perfectly well have been settled by a state commission; but there is a still worse feature about this case. The decision shows that the court, after all of these years of consideration, did not in the least comprehend the situation. The stream is one which receives the direct discharge of sewage from a large town in New Hampshire only a few miles above the factory. It had been previously used for water supply purposes, but had been abandoned for this purpose on account of an epidemic of typhoid fever which was traced directly to the drinking water. The stream had been pronounced by the state board of health unfit for domestic purposes. Furthermore, it is well known that it is practically impossible to purify the wastes from a woolen mill to such an extent that they can be discharged into a relatively small stream without making the water less fit for drinking purposes. The court found, however, that "it does not appear that the offensive matter cannot readily and at small expense be otherwise disposed of. . . . Nor is this a case in which the defendant is simply discharging noxious matters into an already polluted stream. It is expressly found by the master that the water when it reaches the defendant's premises is good, clean, clear brook water, fit for any kind of manufacturing or for domestic use."

The court ordered as follows: "Accordingly a decree should be entered that the exceptions of the defendant should be overruled, and that it should be enjoined from emptying or discharging into the brook upon its premises, above the plaintiff's premises, any acids, soaps, compounds of soap, or of iron, chemicals, scourings, dye-stuffs, sewage or any objectionable substances whatever, in quantities that noticeably or appreciably affect the purity of the waters when they reach the plaintiff's premises, or render them materially less fit for drinking, domestic or other uses at that point than they are when they enter the defendant's premises."

It is hard to conceive that any commission or board charged with the control of inland waters would make a decision of this kind, applying a drinking-water standard to a stream not used for this purpose and already badly polluted by sewage discharged into it outside of the state. Furthermore, such a commission would know that it would be impossible to purify the wastes from a woolen mill of this character so that they could ever be discharged into a small stream used for drinking or domestic purposes.

In both of these cases the complainants were put to a great expense, and such is always the case when the matter is taken to court. This means that unless those who are affected by the foul condition of the stream are wealthy, they must patiently endure it or move elsewhere.

As an illustration of the different method of procedure under state control I might refer to the manner in which the law relating to the pollution of the Neponset River has been enforced by the Massachusetts State Board of Health. The law has been in effect for several years and the board has been working with the manufacturers to ascertain the best method of purifying the wastes from the many different manufacturing plants. Each case has been considered separately and an attempt has been made to secure the cheapest as well as the most efficient plan. A reasonable time has been given to make the necessary changes in the different plants, and it seems likely that the work of purifying this stream will be accomplished without recourse to the courts.

Perhaps a still more important reason for state control is that with state control it is possible to act before the damage is done, while if the matter is left to the courts, it can be settled only after the sewerage system has been constructed, or after the mill is in operation. With a state authority it is possible for the manufacturer or for a city or town to obtain advice in advance as to

whether it will be permissible to discharge sewage or waste into a stream before incurring a large expense in preparing plans or building works.

Experience in Massachusetts has shown that it is exceedingly difficult to clean up a stream which is already polluted by sewage and manufacturing wastes. The factories and the sewerage systems are constructed in such a way that it entails enormous expense to construct purification works, and in some cases it practically means the abandonment of the manufacturing plant. On the other hand, there is comparatively little hardship in so constructing the sewerage system or the manufacturing plant that the wastes can be treated in the beginning.

The state control of inland waters began in Massachusetts practically twenty years ago. Those streams which were foully polluted at that time are still foully polluted. The work which has been accomplished has been in the way of preserving the purity of the streams which were then clean and preventing the further pollution of streams which were already polluted. It is very gratifying to see that the state of Ohio is beginning right and is putting these matters under state control before the streams become so badly polluted that it will be too late.

Mr. Allen Hazen. — One of the great uses of the rivers of our country is to carry away various wastes, the disposal of which would otherwise involve serious expense to municipalities and manufacturers.

This is a most important use of the streams. It is only to be used within reasonable limits, and those limits, as Mr. Pratt intimates, are defined by law. The common law controls until it is modified or superseded by special statutes.

The restriction of the natural and proper use of the streams in this way by arbitrary and unreasonable legislation tends to tax unnecessarily and unjustly many municipalities and manufacturers. There can be no doubt that if such laws had been enacted and enforced, a generation ago, as some state authorities would like to see enforced at the present time, they would have proved a very serious handicap to the development of the country.

The common law may be a cumbersome and expensive way of determining the rights of various riparian owners and of preventing excessive pollutions of some of our rivers, but it is an effective way. It certainly has some advantages, and great advantages, over the special laws which have in many cases replaced it.

Certainly it is not to be questioned that in some cases additional and special legislation is necessary, but it seems to the writer that the greatest care should be used in framing such legislation. There are many points to be considered. Not only must a reasonable view of river pollution be taken, but the laws must provide for a reasonable procedure in determining the rights of different parties.

Under some laws that have been passed it would seem that state officers were given legislative and judicial authority not at all in harmony with our general theory of government; and when such officers exercise such judicial authority, they do it without the restraint of the traditions and rules of procedure which control our courts and insure the protection of the rights of all parties in the decisions that are reached.

Fortunately some over-stringent laws have been found unconstitutional. This is fortunate because it has prevented grave injustice to many parties, and it is further fortunate because the enactment of unduly severe laws and their enforcement certainly does not tend in the long run toward improving the sanitary conditions of the country; and this is the ultimate object which is sought by the author of the paper and by the writer.

Mr. Theodore Horton. — Since it is mainly through a knowledge of the inconsistencies in the laws relating to the purity of inland waters of our different states, gained largely from an open discussion of them, that any advance toward a uniformity of such laws can be hoped for, the writer feels that the author's paper is of especial interest and value to those under whose counsel and advice the execution of these laws is intrusted.

The writer believes that in dealing with the many and varied questions that continually arise in connection with stream pollution, no general policy or procedure can be pursued successfully or in a lasting manner in any state until there is secured among the various states, and especially those geographically contiguous, a much greater uniformity of laws and consistency in policy than now exists. This lack of uniformity is particularly noticeable in the case of the state of New York, owing to its geographical position and the interstate character of many of its streams. New York is bounded by five other states, the protection of the streams of which, as pointed out by the author, is under the control of bodies of men different in organization, working under different laws and in some cases pursuing entirely different policies. With every one of these states there are streams which flow from or into the state of New York and, in some instances, re-enter the state from which they first flow.

Under such conditions, then, it is evidently impossible for the state of New York, or any adjoining state, having a single sanitary code, to adopt a policy with respect to stream pollution that will be in perfect harmony with the policy or practices of the other states. The policy of one state must of necessity work relatively a burden or hardship upon the people or communities of other states, and this apparent injustice will usually create a discontent, and frequently a defiance, of the laws of the state where such policy is the more severe.

The writer believes that it is only through education and a coöperation among state health officials having in charge matters pertaining to stream pollution that any hope of unanimity of legislation and practices can be accomplished. This education should not be limited to a mere gain of knowledge pertaining to water supply, sewerage or stream pollution, for the exclusive use of engineering divisions of state boards or departments of health, but should be extended to local health boards and the people themselves in such a manner and to such an extent as will create a demand for effective and consistent legislation in all of the states. This principle of broader education is considered of such importance in the state of New York that under the present commissioner of health, Dr. Eugene H. Porter, a special division, entitled the "Division of Publicity and Education," has been instituted, and for more than a year has been doing effective work of education in all the branches of public health work.

Along the line of coöperation I believe much can also be accomplished. Sanitary laws in our different states will probably continue to vary somewhat, partially as to result of differences in local and even social conditions, but principally owing to a failure to enact new laws or amend older ones to keep pace with the advance in knowledge and experience gained in some states where greater opportunities or funds are available for gaining such knowledge and experience. A closer intercourse between representatives of health boards of all states would, then, do much in guiding the progress of health work in states less advanced in matters of sanitation and in conserving considerable work and funds now expended independently by different boards in investigations and solutions of identical problems. It would also tend to secure a greater harmony of opinions and practices among all of the states and eliminate the non-uniformity in laws and policy which, the writer feels, is the greatest barrier at the

present time to progress in protecting efficiently and consistently the purity of our inland waters.

Whether the practical application of this idea of closer coöperation can be better accomplished by more formal conferences between health representatives of different states, such as by the joint conference held at Atlantic City in August, 1906, between the heads of the state departments of New York, New Jersey and Pennsylvania with reference to the pollution of the Delaware and Susquehanna rivers; or whether by less formal conferences or meetings between the engineers representing such departments, such as the writer has also had the pleasure of attending on a number of occasions during the past year, is of less importance at this time than the spirit which has prompted these conferences. The unanimity of ideas and purposes which has followed the discussions at these conferences has certainly convinced the writer of the value of such coöperation and given him the hope that this principle can be extended in a practical way to the mutual benefit of all state departments of health.

Prof. C.-E. A. Winslow. — I am inclined to think that when the history of the early twentieth century in the United States is written, one of its most important chapters will deal with the progress of sanitary reform. The adjustment of public and private economic interests at the moment occupies a large share of our attention, but its effect upon human life and human happiness will not equal that of the quiet movement toward purer food and purer water, better factories and better homes. Particularly in water supply and sewage disposal, the last ten years have marked almost an epoch. During that time the cities of Cincinnati, Indianapolis, Jersey City, Louisville, Minneapolis, New Orleans, New York, Philadelphia, Pittsburg, Columbus, Toledo and Washington, with an aggregate population of over eight millions, have carried out or projected important plans for the improvement of the sanitary quality of their water supplies. All through the smaller cities the leaven is working, and progress is being made with special success, under the impulse of aggressive state sanitary authorities, in the commonwealths of New York, Pennsylvania and Ohio. Mr. Pratt's well-balanced statement of the legal principles underlying the campaign for the protection of inland water, and his able review of the progress already made in various states, is, therefore, particularly timely.

There is no longer any valid excuse for infected water

supplies or polluted streams. The development of the process of mechanical filtration has made water purification practicable for all parts of the country. The conviction is steadily growing that no surface supply is safe without treatment, either by slow sand or mechanical filters. Protection of water sheds and storage are useful accessory agents, but the safety that comes from perfect control can only be attained by the use of a naturally or artificially filtered supply.

In sewage disposal, too, the engineer has at last a fairly satisfactory series of methods available for practical application. The work of Cameron, Dibdin and the other English sanitarians in the development of the septic tank and the trickling filter make it possible to secure a stable effluent without excessive expense, even for large cities, in regions where natural sand beds are not available. This solves the problem of purification as far as putrescible organic matter is concerned. The effluents from filters of coarse material are not, however, bacterially purified, and in certain cases bacterial as well as chemical purity is necessary. This fact has turned the attention of sanitarians to a fresh consideration of the problem of removing bacteria. Its solution has not been long delayed. Chemical disinfection of effluents has now been clearly shown to be feasible, and some of us believe that, in certain cases, even crude sewage or septic effluent may be bacterially purified in this manner with advantage. As Mr. Pratt has pointed out, the idea of chemical disinfection, like the practice of sewage treatment at high rates, originated in England.* It is fair to remember, however, that we owe the serious consideration of this process by American engineers to the demonstration of its economy a year ago by Phelps and Carpenter.† Further work now being carried out by Professor Phelps, by the experts of the Ohio State Board of Health, by the Sewerage Commission of New Jersey and by the Department of Agriculture will, no doubt, lead to important further progress.

Even as the matter stands to-day, the engineer can furnish a community with any result in sewage purification for which it is prepared to pay. With sand filters, a clear and bacterially highly purified effluent may be obtained. With trickling beds, organic stability may be effected at less expense, and chemical disinfection will take care of the bacteria if that end be specifically desired.

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* Rideal : *Journal Royal Sanitary Institute*, XXVI, 378.

† *Technology Quarterly*, XIX, 382.

Dr. Channing, the brother of the famous Unitarian divine, when he was once by mistake asked to conduct a religious service replied, "Oh, you have the wrong man. It's my brother who preaches. I practice." The municipalities of the United States have now every facility for imitating Dr. Channing in the field of sanitation. Methods of water and sewage purification will be improved with every year, but good practical methods are now available, and the main thing is to apply them.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the JOURNAL.]

THE USE OF SMALL PUMPING PLANTS IN CONNECTION WITH SEWERAGE SYSTEMS.

DESCRIPTION OF NEWTON SEWERAGE PUMPING PLANT.

By Irving T. Farnham, Member of the Boston Society of Civil Engineers.

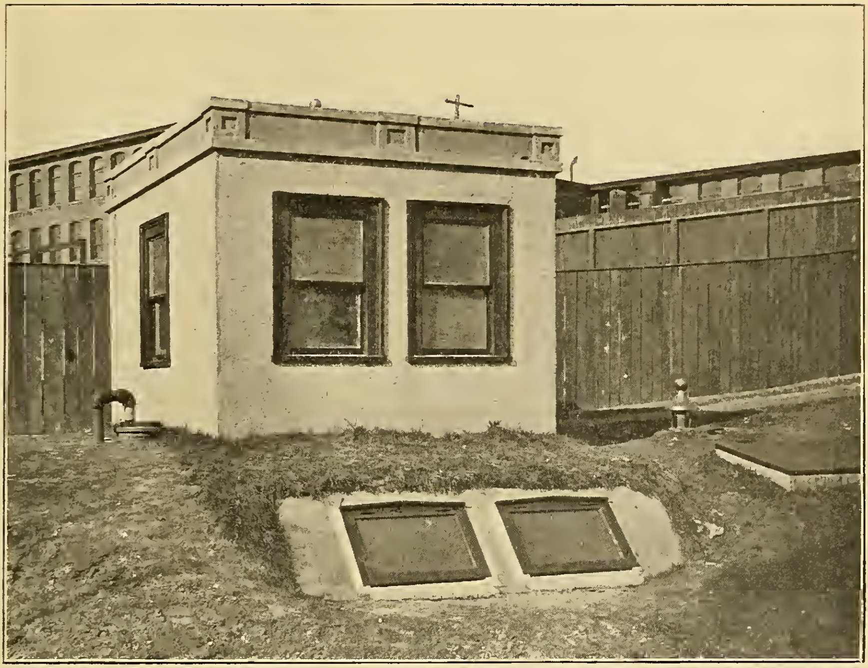
[Read before the Sanitary Section of the Society, January 9, 1907.]

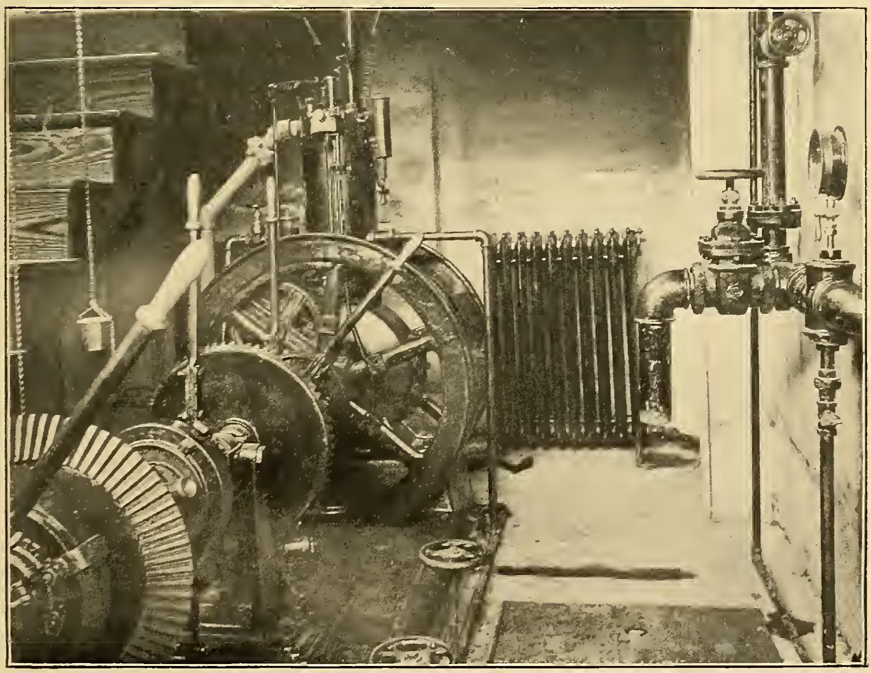
The Newton sewer system will eventually be entirely a gravity system, but the demand for sewers in a small section at Newton Upper Falls made it necessary either to construct a long and expensive line of trunk sewer or to pump the sewage up to a sewer already built. It seemed desirable to save interest charges by delaying the construction of the main until such time as the population on the area which it is ultimately to serve made this construction necessary, and the temporary expedient of introducing a pumping system was resorted to in 1903.

The topographical conditions were such that the plant could be located on land owned by the city near the water works pumping station, and at a point where the sewage can ultimately be intercepted by the trunk sewer. The area served is 22 acres, containing 30 houses, with an estimated population of 160, and the Saco & Pettee Machine Works, which employs about 600 hands.

The collecting system consists of 2 640 ft. of 8 in. vitrified deep and wide socket pipe laid with cement joints. The sewage is discharged into a circular concrete well 18 ft. in diameter and 6 ft. deep, which is divided diametrically into two chambers by a vertical partition provided with a gate. By stop planks the sewage may be diverted to either section, thus allowing the cleaning of one section or repairs to pump while sewage is discharging into the other. The sewage, before entering the well, passes through basket screens of wire woven 1 in. mesh.

Above the pump well, but below the surface of the ground, was constructed the engine chamber, 9 ft. by 17 ft. inside measurement, and above the ground is a concrete house, 9 ft. by 11 ft. inside measurements, which provides light and ventilation and affords an entrance to the engine chamber. The pumping machinery is in duplicate and consists of two $3\frac{1}{2}$-in. submerged





Newton Sewerage Pumping Plant.

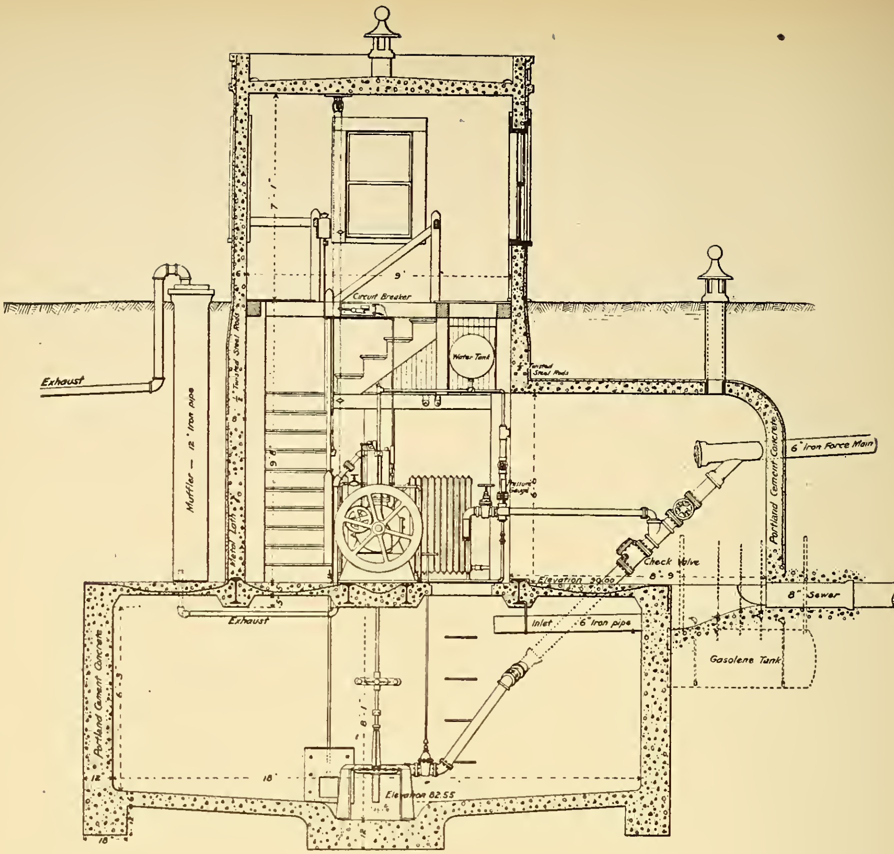
centrifugal pumps mounted on vertical axes and operated by two 6 h.p. vertical gasoline engines, which are connected with a horizontal shaft geared by bevel gears on to the vertical shafts of the pumps. By means of friction clutches on the engine shaft either engine can be used to operate either pump, both engines to operate one pump or both pumps running together. This provides great flexibility of operation and has prevented any delays in pumping when either pump or engine has needed repair or is otherwise out of service. The pumps discharge the sewage through a 6-in. iron force main, 1 430 ft. long with a maximum lift of 30.7 ft. A check valve upon the discharge pipe prevents the back flow of sewage from the force main into the well after the pumps are stopped.

The contract for the installation of machinery, made with the Charles J. Jager Company, required the delivery of 150 gal. of sewage per minute. Tests made after the pumps had been in operation a short time showed a discharge of 210 gal. per minute, and the pumps under daily working conditions are exceeding the rated capacity. The discharge main was laid at the side of the sewer trench near the surface. At each sewer manhole a special casting provides a means for opening the force main for inspection and cleaning, but during the three and a half years which the pumps have been in operation there has been no necessity for such opening. The discharge through it now is apparently as free as when it was first put in service.

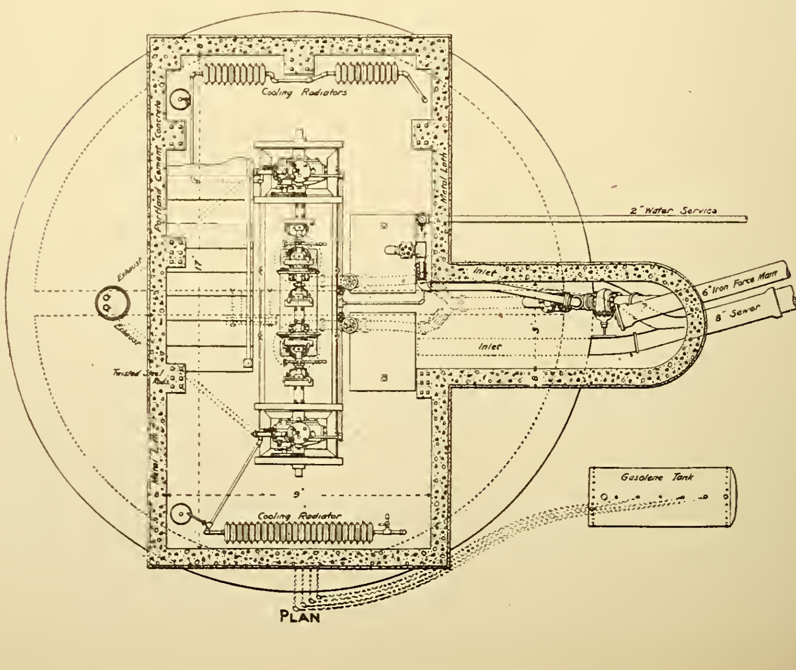
Operation.

The pump, being near the water works pumping station, is operated by one of the firemen, who goes to the plant two or three times daily, and starts one pump. A Winslow recording gage, electrically operated at the water works pumping station, indicates the amount of sewage in the collecting well and also keeps an accurate record of the flow of sewage and operation of the pumps. The attendant, after starting the pumps, returns to his work at the water works station, and when the sewage is discharged an automatic float cuts off the electric igniter and stops the pump. One of the laborers from the flushing gang goes to the plant one day each week, cleans out the screens, flushes the sludge by means of brushes to the center of the pump well, so that it may be pumped through the main, and gives the plant a general slicking up.

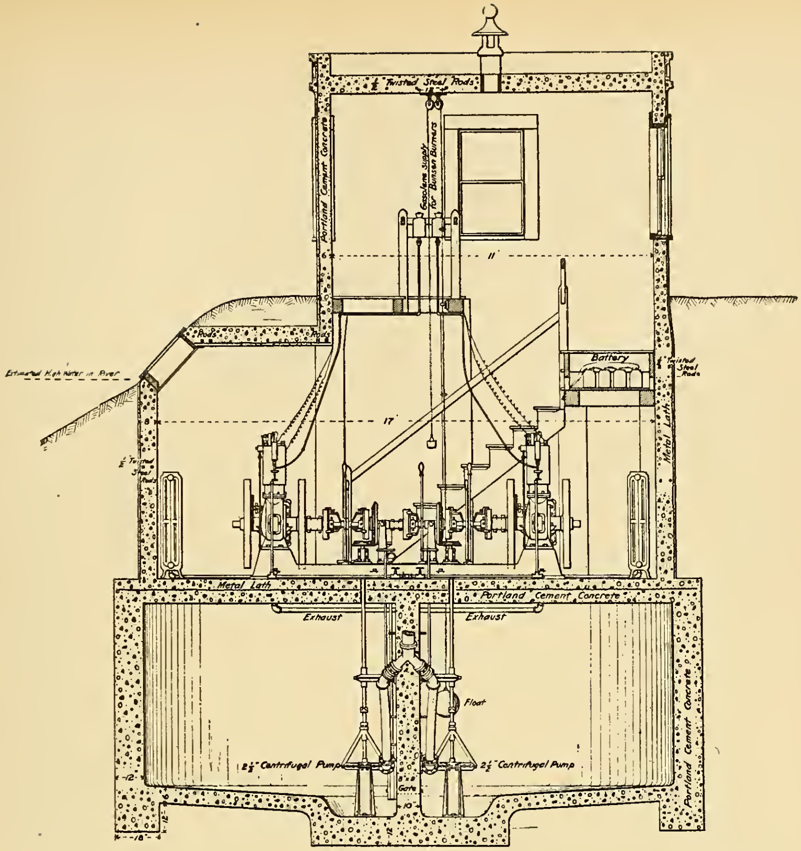
From an analysis of the daily charts made by the automatic recording gage the following facts are obtained:



SECTIONAL ELEVATION
— SIDE —



PLAN



SECTIONAL ELEVATION
— FRONT —

The plant handled, during the years 1905 and 1906, an average of 25 565 gal. daily. The maximum entering the sewage well on any one day was 53 700 gal. The leakage of ground water for the year 1905, as indicated by the inflow between the hours of midnight and 4 A.M., averaged 3 100 gal. per day, or 12.5 per cent. of the total sewage pumped. This is equivalent to 860 gal. per day for each 1 000 ft. of sewers and house connections. The maximum leakage in one day was 9 700 gal., at which time there was probably considerable water entering at the tops of the manhole covers.

COST.

The cost of the plant was as follows:

For sewage well and pumping station	$2 400.00
For construction of force main and connections	2 100.00
For installation of machinery	2 200.00
Total	$6 700.00

The average yearly cost of operation for the three years 1904, 1905 and 1906, has been as follows:

Labor and attendance	$108.50
Gasoline	145.85
Maintenance and repair of plant	66.00
Oil, batteries and other supplies	85.87
Total	$406.22

The results of operation for the years 1905 and 1906, tabulated in the form recommended by this Sanitary Section, are as follows:

B. Fuel for engine.
- (*e*) Kind and grade .... Gasoline, 72 degrees test.
- (*f*) Average cost .... 16c. per gal.

3. Amount of fuel consumed per year .... 1 168 gal. gasoline.
4. Total pumpage per year with allowance for slip .... 9 331 225 gal.
5. Average static head against which pump works .... 28.75 ft.
6. Average dynamic head against which pump works .... 34.85 ft.
7. Number of gallons raised 1 ft. per gal. gasoline 229 686
8. Cost of pumping figured on station expenses per million gallons raised 1 ft. (dynamic) $1.35

The cost of fuel, which in this case practically represents the cost of power, was 58 cents per million gallons raised 1 ft. dynamic equals 15.5 cents per effective horse-power developed by pump and engine; assuming efficiency of 33⅓ per cent. for pumps. This gives cost of 5.11 cents per horse-power developed by pump.

The plant as a whole has very satisfactorily performed the service for which it was intended, but a description of a plant of this kind would not be complete without a mention of some of the outs and difficulties encountered in its operation.

To my mind the most serious difficulty is one of human weakness rather than that of mechanical inefficiency. The burden rests upon some one to see that the well is kept pumped out, and if there is no emergency overflow any neglect in the pumping causes serious trouble. In this case, the collecting well was made small, as the plant was designed for temporary service and was so near the water works pumping station that the pumps could be started several times daily if necessary. The pump well and engine chamber being below the level of the river, no emergency overflow could be provided, and in two or three cases the sewage has risen above the level of the floor before the pumps were started.

When the plant was first put in operation no screens were provided, as Mr. Jager was quite confident that the pumps would

throw out anything that could come to them through the sewer, and he was nearly right, but there was one substance that he did not reckon on, namely, cotton waste, a large amount of which entered the sewer from the works of the Saco & Pettee Machine Works. This waste would knot up and collect around the suction pipe, and when finally drawn in would completely stop the discharge. The basket screens now intercept the waste, and this is about the only service which they perform. The mesh is very quickly filled with paper and the sewage overflows from the top so that the screens act as a settling sump to catch the waste.

Some difficulty was experienced with the current for the electric igniters, but although Bunsen burners are provided for use in case of emergency we have always been able to maintain an electric current. The difficulty seemed to be with the cut-off, which would short-circuit the batteries and run them down. This was corrected by providing a spring held with a latch, which is tripped by the float when the well is emptied, throwing the switch completely out of contact.

Other trouble was caused by the fine sand which comes in from the foundry of the machine works. This sand would be carried up through the discharge of one pump, and at the point where the two discharge pipes join would settle back against the valve of the second pump and cake in so hard that the pump would not throw it out. This difficulty was overcome by a little more care in the cleaning and flushing, water being flushed back through the pumps occasionally with the pressure of the water main. I believe that these are all the troubles which we have had.

The cost of operation has increased somewhat each year, due to the increase in the cost of gasoline, the increase in the amount of sewage handled and the increase in the amount of attention which is given to the pump for the purpose of avoiding the difficulties above mentioned.

DISCUSSION.

Mr. Frank A. Barbour. — The necessity of reaching elevations sufficient for the installation of disposal plants, or the economy of treating a system of interception sectionally, either because of intervening high land or territory generally too flat to permit of good gradients, often leads to the use of pumps in sewerage works.

In all cases the necessity for pumping must be proved, particularly to the local authorities, who have a well-grounded aversion to the adoption of anything but a gravity outflow. At the

same time it is generally advisable to pump if a better soil can be obtained for filtration, even though a fairly workable field may be reached by gravity. It also frequently pays to pump the entire sewage when a portion in any case has to be so handled, though a large part of the town may possibly be intercepted by gravity. Sometimes where a gravity outfall can be proved economical if figured on some projected curve of future population, it is cheaper to pump under present or probable immediate conditions. This is particularly true in New England towns which, as experience proves, are apt to develop a very hesitating growth after reaching a certain point.

The great argument against pumping in the case of small installations has been the labor charge; this is particularly true when economy in the design of a system of interception dictates the division of the area into districts and multiple pumping. With steam pumping, local attendance at each station is required and a storage capacity limiting the pump run to certain hours is a necessary adjunct. To localize the labor at one point, compressed air, under the Shone system, is of considerable value, but is generally applicable to a limited zone of distribution and from the speaker's experience of the few plants he has examined is not economical.

The more nearly continuously a pumping plant can be made to operate at a uniform rate, the more economical is the result, provided the labor account does not offset the saving in the decreased storage capacity, lessened size of force main and reduced friction head thus made possible. With a steam plant a reservoir large enough to hold the sewage during the hours the pumps are not running and a force main adapted to the pump rate are required. If the amount of sewage to be handled could be accurately predicted and a pumping unit with a capacity equal to the average daily discharge adopted, then a reservoir only large enough to equalize the hourly variation would be necessary. This cannot practically be done and the nearest approach to uniform discharge is obtained by dividing the plant into such a number of units as will most nearly approximate in their capacity the rate of inflow; in other words, by dividing the total power into units best capable of handling the load curve. With such an arrangement the reservoir can be reduced to a size only sufficient to prevent too frequent starting and stopping of the units, and the force main can be designed on the basis of the maximum rate of inflow for the period in the future which it is economical to consider. This continuous discharge is often extremely desirable

in disposal work where either purification is effected or the sewage disposed of by dilution.

Such frequent starting and stopping practically necessitates automatic arrangements, and for this electric power is apparently the best adapted. Experience has proved the possibility of operating such plants with practically no attendance except for oiling and examination of switches. It is well to call attention to the fact that no apparatus with moving parts will operate indefinitely without some care, and the inherent danger in the use of automatic pumping installations is the tendency to altogether neglect such plants. This human weakness, however, is no argument against their adoption under intelligent management.

The plant at Saratoga, N. Y., is of the type above described, consisting of 3 units of 20 h. p. induction motors, directly connected by vertical shafts to three 6-in. centrifugal pumps, the pumps being submerged in 3 separate wells, with floats in these wells so arranged as to start and stop the motors by the rise and fall of the sewage. The capacity of each unit is 1 500 gal. per minute with one pump working against a head of 28 ft.; 1 200 gal. per minute with two pumps working against a head of 38 ft., and 1 000 gal. per minute with all three pumps against a head of 42 ft. The combined efficiency of pumps and motors was, by test, proved to be about 35 per cent. The capacity of pump well is 10 000 gal., or only sufficient to balance the operation of the machinery. The amount of sewage handled daily varies from 1 500 000 to 3 000 000 gal. The cost of the plant was $5 400, including pumps, motors, automatic starting apparatus and all interior piping and valves.

At Hudson, Mass., two 15 h.p. induction motors, using a three-phase current of 60-cycle frequency, directly connected by vertical shaft to 5 in. centrifugal pumps, serve to lift the sewage to the elevation of the disposal plant. The current is obtained from the municipal electric plant at a primary voltage of 1 080, which is stepped down by static transformers to 500 volts at the motors. The pumps in this case are set in dry wells at an elevation below the height to which the liquid rises in the adjoining sewage well, with suctions laid through the concrete dividing wall into this collecting well, while the pumps are, therefore, dry and accessible for use, ready primed with each rise of the sewage in the collecting well. The normal capacity of the pumps is 500 gal. each when two units are working against a total head of 35 ft. A combined efficiency of 42 per cent. was guaranteed, and by test this was slightly exceeded.

Wherever vertical shafts are used the division of the moving parts of motor and the impeller thrust by a slip coupling seems to be desirable. The thrust bearing for the vertical shaft is an important element in the design. At Saratoga, where a bearing of several inches diameter, with alternate loose rings of brass and steel submerged in oil was employed, considerable trouble was encountered because of heating. At Hudson, a regular marine propeller bearing, with an oil-collecting pan and the oil lifted and circulated by centrifugal force, as is done in motor work, was used with entire success.

As stated above, in Hudson the pumps were placed in dry wells to make inspection easier than when directly submerged as at Saratoga. This arrangement has emphasized the necessity for particular care in obtaining a tight pump-casing so as to prevent the entrance of air into the pumps.

In both the Saratoga and Hudson installations time limit relays have been installed, which automatically cut out the current in case of stoppage of the motors or burning of the switches. The floats are so set that the first pump starts with the sewage at a certain level, and if the inflow is greater than the capacity of this pump the sewage rises to the level where it operates the float governing the second pump. This second pump, coupled to an alternating motor, runs at constant speed and, starting against a closed check with no discharge, develops the necessary pressure to lift the check and begin pumping. Where power is drawn from a lighting circuit the starting torque of motor may dip the lights for a fraction of a second unless special apparatus is inserted in the line to prevent this action. Alternate motors, started and stopped automatically, cannot be varied in speed with success. With a certain frequency and number of poles a fixed number of revolutions per minute results. The variable factor in obtaining the desired pump capacity is in the radius of the impeller. Motors with a multiple number of poles can, however, be obtained, the number being changed by the attendant so as to change the speed in the inverse ratio to the poles in use. With direct current the series parallel method of control can be utilized to automatically vary the speed in such a way as to adapt discharge to inflow within certain limits. Where direct current is used the motors cannot be safely subjected to the same overload as with alternating motors, and in order to prevent comminator difficulties under the torque, developed in starting centrifugal pumps, large relative motor capacity must be provided.

The cost of the Hudson plant was $3 600 complete, including motors, pumps and all interior piping and electrical apparatus.

At Fredericton, N. B., an electrical plant, consisting of two 15 h.p. motors, directly connected by vertical shafts to two 5-in. centrifugal pumps, is being installed to pump the sewage during such period as the river is above the elevation of the outlet of the sewer. This plant, utilizing a three-phase alternate current, is necessarily designed to give a circumferential speed of impeller sufficient to discharge the desired amount per minute — 500 gal. — against the maximum height of water in the river. This height varies 20 ft. and, with the short length of force main, is the governing factor in determining load. In this case, however, with constant circumferential speed, it is found that the maximum load on the motor occurs not with the maximum head but with a lower head. This because of the fact that in the case of a centrifugal pump the discharge increases in greater inverse ratio than the reducing head, and the maximum load occurs at some intermediate point between the maximum and minimum head, the exact place of which depends upon what may be called the characteristic of the pump and this upon the curve given the impeller. Each centrifugal pump has its own characteristic and a breaking-down point beyond which discharge will not increase beyond the inverse ratio of the head. This is a phase of the problem which must be taken into account wherever the head is liable to change either because of a varying difference between source of supply and point of discharge or in the case of a force main which may empty because of reduced friction head at the time of starting the pumps. Unless care is taken in the selection of the impeller curve it is possible, under reduced head, to bring such a load on the motor as to burn out the windings.

The cost of the Fredericton plant was $4 000, including the motors, pumping, piping, time limit relays and automatic starting and stopping apparatus. This is equivalent to about $3 000 in New England. The guaranteed efficiency is 52 per cent. and there is a proviso in the specifications that for each 1 per cent. difference between the guaranty and that actually obtained by test, a penalty of $50 will be imposed or bonus paid. In this connection it should be noted that high efficiency in handling sewage sometimes increases the tendency to clogging of the pumps because of the decreased impeller clearance necessary to this efficiency, and it is sometimes better in sewage work to adopt a pump with lower economy or one requiring less screening of the sewage.

One of the advantages of electrical pumping is the possibility

of placing the apparatus below the ground surface and without any building. At Atlantic City, because of the flat character of the country and the small elevation of the streets above tidal level, several pumping stations are to be installed. These are to be placed below the streets or sidewalk, the stations being lighted through the roof with glass sidewalk lights. The screens will be raised by hydraulic lift above the elevation of the ground and there cleaned in a manner similar to the old sidewalk elevator.

At West Chester, Pa., the peculiar topography of the city renders absolutely impossible the collection of the sewage at one point, making it necessary to install two pumping stations. These will be similar to the units at Hudson and Saratoga, but in this case single-phase current will be used. The difficulty with such current has been the overcoming of the starting torque, but in small motors this can now be done.

In any case the use of gasoline or oil engines, gas producers, steam or electricity must depend altogether on local conditions. Where a number of small plants are to be installed, widely distributed in location, and where current can be obtained at a reasonable cost, the automatic possibility of electric operation will usually render this the most economical and advisable. In the case of Saratoga, where power is obtained from the Spier's Falls Plant on the Hudson, there is no doubt that in actual cost of power this plant is far more economical than would be possible under any other method. In the case of Hudson, where the current is obtained from the municipal plant, the actual charge is between different departments of the town and is largely one of book-keeping. It is to be noted that the use of electric current, with the greatest demand during the hours when the amount of light required is at a minimum, serves to smooth out the load line, and it is probable that 2 or 3 cents per kilowatt hour is as high as can reasonably be put down as the actual cost. In such cases electricity will compare favorably in point of cost with any other form of motor. The possibility of small artistic stations, odorless and noiseless, without chimney or exhaust pipe, is a feature to be counted in favor of electric pumping, particularly in summer resorts or high-class residential districts, where the absence of obtrusive evidence of the object of the building is important. Pumping is sometimes thus made possible where steam or gas engine plants would not be tolerated.

The use of heavy oil engines is suggested by the rising cost of gasoline, and in Canada, where the price of the latter makes its use practically prohibitive, it is the only form of oil engine

which can reasonably be considered from a municipal standpoint. In connection with such type of motors, the best method of attachment between motors and pumps is an interesting phase of the problem. Gearing is usually noisy, and while this undesirable factor can be reduced by the use of rawhide gears, no such plant can be compared in smooth working with a steam engine or directly connected centrifugal pump. In hitching up engines with centrifugal pumps the use of silent chains is worthy of consideration. With a guaranteed efficiency of 98 per cent. and the short distance between centers, this method has features in its favor beyond the old belt, the only offsetting condition being the high price charged for these chains.

In the past year there appears to be a growing appreciation of gas-producer plants. Such plants, while demanding little attention, do not permit of automatic operation. In point of economy, however, they apparently offer inducements greater than that possibly obtainable under any other method. With the plant now being installed at St. Stephen, N. B., a guaranteed duty of 115 000 00 ft.-lb. per 100 lb. of coal is specified, this to include all standby losses, with the pumps actually operated 8 hours per day and banked 16 hours. In this connection the small consumption of fuel used during banking in a producer is an important consideration.

Mr. C. O. Rogers. — Gentlemen, I want to thank you for the opportunity of being present. I did not attempt to prepare any formal paper, as I did not expect to be called upon quite that way. One or two points occurred to me, however, in listening to Mr. Farnham and Mr. Barbour. I was quite intimately concerned in the design and erection of the plant at Newton Upper Falls and have felt interested in that plant from the time of its starting to the present time.

I am glad to notice the fuel observations which Mr. Farnham brings to our attention, and in that connection I want to say that the fuel which we should expect that engine to consume in the case of a test of any duration that we cared to give it, under expert handling and proper adjustment, would probably be one sixth of a gallon per horse-power per hour, or possibly somewhat better. Mr. Farnham's results for the entire year show a consumption of only a little better than one third of a gallon per horse-power per hour. Possibly this undue difference may be traceable to the difference between expert handling of the engines and the comparatively inexpert handling which Mr. Farnham's operator gives them.

In plants of that size and smaller, with several of which I have been connected, it seems to me that it is wiser to look for reliability in the operation of the machinery rather than for an extreme of economy in fuel. The incidental expense due to flooding of the sewage basin, or due to failure to start the machinery on the part of the attendant, is much more important than the consuming of a gallon or two of fuel more in the day's run. This point of not looking for the highest possible efficiency relates both to engine and pump. In the design of a centrifugal pump, the highest possible efficiency is gained by careful adjustment of the form of the impeller, and also of the clearance between that impeller and the shell surrounding it. If the clearance is brought to the smallest point, while the efficiency of the pump is increased, the ability of the pump to pass heavy solid matter, such as is likely to come to it in the operation of a sewage plant, is greatly reduced; and under those conditions, the cost of cleaning the pump overbalances the gain in efficiency. As a consequence, in designing we are accustomed to give them undue clearance and stand the loss due to the lesser efficiency. That seems to be the wisest plan.

As regards a comparison between gasoline and electric power, it is unquestionably a matter for local selection. The conditions governing the individual plant must decide on that point. In the case of the electric motor, it is always possible, by means of undue overloading, to burn out the motor if the fuses do not protect it. In the case of the engine, it is absolutely impossible, if the engine is provided with oil at the proper points and there is water in the jacket, — it is impossible for overloading to damage the engine. It may require additional attendance to start again if overloaded to point of stopping, but does not injure the machinery itself. That is one point that has not been properly brought out.

Mr. Lewis D. Thorpe. — The use of internal combustion engines has become so general that I am afraid anything I may say will perhaps be an old story to many of you. I have also had very little time to look up and prepare notes, but will try to give a brief description of a sewage pumping plant designed by the late Freeman C. Coffin for the city of Charlottetown, P. E. I.

The plant was constructed during the seasons of 1898 to 1900 and has been in continuous use ever since. The sewage from a portion of the city is discharged by gravity, but there are two sections, one on each side of the gravity section, whose sewage has to be pumped to points on the gravity line. It is then

discharged out of the main outlet. Two pumping stations were built, one for each section. The west section is composed of about 5.5 miles of from 6-in. to 12-in. sewers, and the force main is 10-in. cast-iron pipe 800 ft. long. The east section has about 3 miles of the same sizes, and the force main is 10-in. and 940 ft. long. The west reservoir has a total capacity of 75 000 gal., and the east reservoir, 65 000 gal. Each station is provided with a 7 h.p. horizontal Otto gas engine, and one 3-in. and one 4-in. submerged centrifugal pump, which are driven by belts from the main shaft on the engine, the shaft being connected to the engine by a friction clutch. By a simple float arrangement the engines are arranged to stop when the reservoir is emptied, and at the same time to cut off the supply of cooling water and, by opening a cock, drain the jacket of the engine. The cooling water is taken directly from the city mains. Each engine is also provided with a gasoline attachment that can be placed in position in a short time and gasoline used in place of gas. A Winslow recording gage connected to each station is located in the office of the sewerage commissioners. These gages indicate the height of sewage in the reservoirs at all times. The height is also recorded on charts. These charts give a continuous record of the height of sewage in the reservoirs, and also the date of pumping. Several brake tests were made with the engine at the west station under varying loads for the consumption of gas per horse-power. The following are some of the results obtained:

1.12 h.p. .... gas used, 59 cu. ft. per horse-power hour.
2.23 h.p. .... gas used, 39 cu. ft. per horse-power hour.
3.33 h.p. .... gas used, 30.6 cu. ft. per horse-power hour.
5 h.p. .... gas used, 24.6 cu. ft. per horse-power hour.
7.52 h.p. .... gas used, 23.2 cu. ft. per horse-power hour.

Repeated tests were made and the results were in each case about the same as the above. Several pumping tests were also made at the west station with practically the same results in each case. During a two-hour run, made with the 4-in. pump, 71 230 gal. of sewage were pumped, or 594 gal. a minute, against a total head of 30.76 ft., the engine running at 280 rev. per min. and the pump at 685 revolutions. The total amount of gas used for this run, 345 cu. ft., would be at the rate of 4 843 cu. ft. per million gallons pumped. This at $1.25 per thousand cubic feet would cost $6.05 per million gallons, or 20 cents per million gallons pumped 1 ft. high. The work done as measured by the sewage pumped was 4.62 h.p., or 61.7 per cent. efficiency.

A test was also made of the 3-in. pump with the follow-

ing results: Length of run, 2 hr.; speed of engine, 304 revolutions; speed of pump, 795 revolutions; the total amount pumped, 52 200 gal., or 435 gal. per minute, against a total head of 28.35 ft. The gas used during this test was 351 cu. ft., or at the rate of 6 725 cu. ft. per million gallons. This, at a cost of $1.25 per thousand cubic feet, as was paid in Charlottetown at that time, would be $8.40 per million gallons. The amount of work done, as measured by the sewage pumped, was in this case 3.12 h.p., or about 41.8 per cent. efficiency.

The pumping plants are very simple to operate and require very little attention. I have repeatedly started the engine and gone away leaving it to take care of itself, not going near it again until it was necessary to pump the reservoir out, and never found any trouble. It usually took about 20 minutes to oil the engine and bearings and get it to going smoothly.

The total cost of the pumping machinery erected was about $1 400 for each station. This does not include the cost of recording gages.

Mr. F. H. Hayes. — I do not know that I have very much to say in addition to what has already been said about handling sewage by centrifugal pumps, not having had as much experience with these pumps as with the double-acting piston pumps. At Pittsfield, Mass., we have our largest installation of the double-acting piston pump. This is a triplex, horizontal, electrically-driven pump; it handles 3 500 gal. per minute, and delivers this amount of sewage through 2 400 ft. of 24-in. pipe upon specially prepared beds. The electric current is furnished to the city by a local company, for an 8 hr. day-time run, at a very reasonable price, and if a longer run is required, owing to any emergency, there is an additional charge therefor. The plant has been in operation for five years and we have lately had the pleasure of receiving an order for an 8 000 000 gal. triplex sewage pump to go alongside the first one.

The 50-ft. head against which the Pittsfield pump works is practically the same as the heads named for the centrifugal pumps of which you have heard to-day; but when the two styles of pumps are working under the same conditions we claim the greater efficiencies are with the piston pump, and also that the degree of efficiency will be much longer retained by the piston pump.

In the matter of first cost, the odds are greatly in favor of the centrifugal pump. But when the purchase of a sewage pump is being considered, not only must the first cost be taken into

account, but the amount of sewage to be handled, the disposal which is to be made of it and the suction lift.

You will see that on the whole it really comes back to a matter of arithmetic, with this exception: If the centrifugal pump refuses to operate when power is applied, it is as a submerged pump difficult to inspect, and, unfortunately, it has been our experience that submerged pumps are most wanted in times of emergency and most apt to be inoperative at such times. If a piston pump becomes inoperative it certainly has the merit of being where it can be easily gotten at, and therefore is more readily inspected and kept in repair.

We are now getting ready to install at Framingham, Mass., an electrically-driven duplex piston pump to go alongside of steam pumps which have been there for nineteen years. I think the cost of running the electrically-driven pump and the steam pumps will be watched with a great deal of interest, the experiment never before having been tried under such good conditions for determining these data.

When bids were called for on this Framingham machine we were asked for steam-driven machines and given the privilege of making prices on power machines driven either by gas-producer engines or any of the internal combustion engines. When bids were first called for, an electrically-driven pump was not to be considered owing to the high price charged for the electric current by the Edison Company. Later an acceptable proposition was received from the Edison Company for the electric current, and the bids for an electrically-driven power pump were entertained. The pump we are preparing to install has a capacity of 2 000 000 gal. in 10 hr., and the run is to be made in the daytime when the Edison engines are underloaded.

You will note that the Framingham and Pittsfield pumps are similar except that the Pittsfield pump is triplex while the Framingham pump is duplex. Both pumps are fitted with clapper valves allowing free passage for the sewage material. We have been asked to put in vertical triplex pumps with ball valves, and have installed some in small sewage stations, where they are doing good work.

One of the great troubles which comes to all sewage pumps is the result of incorrect screening, and we learned this very early in our Pittsfield experience, for the first screens were so coarse that they allowed the passage of cotton waste, towels, stones, etc., to the pump. After clearing the pump valves, new and finer screens were put in place and the trouble has not arisen since.

The hardest thing to prevent from reaching the pump is cotton waste.

Mr. Johnson. — I think Mr. Hayes can give us some interesting information about trouble experienced with the gearing at Pittsfield.

Mr. Hayes. — In regard to the gearing at Pittsfield, when it was put in we did entirely as we were called upon to do. We furnished a double-geared pump and the inter-gearing had wood teeth. The pump when started was very noisy and could be heard for a long distance and the inter-gears would not hold, going to pieces rapidly. As a consequence we changed from direct connection to belt drive. The pump which you would see in Pittsfield to-day is entirely belt-driven, and from this experience, wherever we can, when considering power installations, we insist on belt connections instead of direct connections. If, however, direct connections must be furnished, the noise can be somewhat lessened by the use of rawhide pinions.

In Pittsfield, owing to the changed mode of connections between pump and power, we had to use two belts. We would recommend, however, wherever possible, the use of one wide belt, The excessive cost of the silent chains prevents their common use on electrically-driven pumps. We have used some of them with good success. We have one at Gardiner, Me.; it is not, however, on a sewage pump.

In all cases where I am asked for advice about how a power pump shall be driven, I say, Belt it.

A Member. — I want to ask Mr. Hayes what he would use in the case of a triplex electrically-driven machine.

Mr. Hayes. — I should use the belt. It is to be demonstrated in the coming week at Dover. Excuse me for mentioning these things; they are the installations I know of, and so speak of them. At the time these bids were called for, we were asked to make prices on double reduction gears, and we told them the noise of such gears would be obnoxious to their people, with the result that a belted pump was ordered. This Dover pump is electrically-driven belt-connected vertical, and has a capacity of 2 500 000 gal.

There is another point I would like to call to the attention of the gentlemen present. Many times when we are asked to make prices on electrically-driven pumps and motors we are asked, "How long can we leave them alone when running?" Some people would like to leave them alone for 24 hr. But so far as our experience goes it is not good judgment to do so. A

plant that will cost from \$2 000 to \$5 000 requires and is worthy of some care, and it should be seen as often as every 3 or 4 hr. At least this is my judgment, and it is the advice I give in answer to the above question. I know of places, where our pumps are running in connection with oil engines, where they are shut up at night and left to run until morning, and so far no trouble has ever resulted. But if trouble came to them, the resulting cost might be a good deal more than the little money required to give them a reasonable amount of care during the night.

Mr. F. L. Fuller. — I have had experience with two pumps of this kind, both direct connected. The noise was excessive, which is largely unavoidable under such conditions. At Franklin, N. H., even with a rawhide pinion, it is difficult for two people to converse with any satisfaction. The pump is an 8- by 10-in. triplex, electrically-driven, and is located in a concrete building or pumping station 22 ft. long by 20 ft. wide. At Uxbridge, Mass., an 8.25- by 10-in. triplex pump, also electrically-driven, is located in a stone and brick pumping station 24 ft. long by 22 ft. wide. This plant is not as noisy as the previous one. It would seem improbable that the difference in the materials of which the buildings are constructed should affect the amount of noise produced in running the machinery, although it is, of course, not impossible.

Mr. Farnham. — On the subject of gears. That part of the Newton plant gave me some uneasiness, because I knew they had not been entirely satisfactory in other places. However, Mr. Rogers worked the problem out and assured me he could put in gears that would not be noisy and would give satisfaction. And I will say that they have been entirely satisfactory. There is very little noise from them. The engine chamber is small, and, having masonry walls, sounds resound considerably, so that while you are in the pumping chamber you hear considerable noise, but a little distance away you can't hear it at all. The plant is within 40 ft. of the street and I hardly think that you'd know the plant was running unless you listened for the puff of the engine. Perhaps Mr. Rogers will tell us more about the gears.

Mr. Rogers. — When we have the problem before us of driving the shaft of a submerged centrifugal pump from the horizontal shaft of the engine, one of the prime requisites is that the drive shall be positive. The plant may be left for a considerable time without attendance and the connection between power and pump should not be lost. The gear drive, of course, answers that difficulty beyond all doubt so long as it is properly designed

and strong enough to drive without breakage. In regard to the Newton Upper Falls gears, they are of bronze and cast steel working together, and are planed bevel gears with ample face. We find that in adding to the face of the gear within reasonable limitations we reduce the amount of noise connected with it. We have also found, in one or two other instances, as well as at Newton, that the noise could be reduced by breaking the continuity of the gears themselves. We have reduced the noise in a number of cases by sawing into the rim at different points in the section, so as to break up the continuity.

The first we put in of the geared type was at the sewage pumping plant for the Dana Hall School at Wellesley. I think that was put in in 1902 — a 2-h.p. gasoline engine operating a 2-in. pump with a capacity of 60 gal. per minute against 14 ft. of head at the time it was put in. There have been improvements since, so that they have had to increase the head against the pump to 25 or 26 ft. We are now delivering to the new location about 40 gal. per minute against the increased head. The gears here are also of bronze and cast steel and the pumping machinery is located inside a wood-walled pit, where we don't get the reverberation due to concrete walls, and it is not unduly noisy. It is not absolutely quiet, but it doesn't produce more than a local sound, which hardly comes out of the pump room. It is almost invariably the case that sewerage buildings are located in a place where local noise is not objectionable, and this noise is purely local. But the disadvantage produced by these local noises is more than balanced by the positive drive.

Mr. Hayes. — Might that not be overcome in a general way by using the wood-tooth gears?

Mr. Rogers. — The gears are hardly large enough to permit of the mortised tooth. The larger gear is about 16 in. in diameter and something like a 4 pitch. It is too small to attempt to use the mortised tooth.

Mr. Weston. — Doesn't the length of the shaft the gears are on have something to do with the noises?

Mr. Rogers. — If the shaft is rigidly supported, I can hardly see how that can have any effect. If the shaft is permitted to vibrate while running, it would, of course, have a great effect.

Mr. Leonard Metcalf. — In connection with the chain-drive, it may be interesting to give an account of a plant I saw this summer, which was installed in a theater in Chicago by the Allis-Chalmers Company. They showed me their triplex pumps,

which are driven by the noiseless chain. The engineer told me that they had been in use about four years and had never given him any trouble.

Mr. Weston. — I should like to ask Mr. Rogers what his opinion is as to the position which the end of the suction pipe should occupy with reference to the bottom of the pit.

Mr. Rogers. — My conclusion was that it should be placed near the bottom, so that the pumps should be as near to the sewage proper as possible, and so that the pipe line should be just as short as possible. Mr. Farnham spoke of the workmen going in every week and stirring the bottom up. I think that is very essential.

Mr. Weston. — Then you would place the end of the suction pipe as low as possible in the pit?

Mr. Rogers. — Yes. At the risk of making the Newton Upper Falls plant an unwelcome visitor, I want to speak about the heating of the station. The pump room containing the engines is below the ground about 8 ft. The gasoline engines used there for power naturally generate heat and require water in their cylinder jackets to keep them cool. In developing the cooling system in that plant a suggestion came to us to use a system of radiators around the walls of the room, circulating the water through the engine jacket and then through the radiators and overhead expansion tank and thence back to the engine jackets. The location of the engine room and this circulation water supply system, with the necessary starting of the system about three times a day, every day, just about supplies the heat necessary to keep that plant secure against freezing. Mr. Ross tells me there has never been any difficulty of this kind in that station.

A Member. — Did you ever use oil in these stations?

Mr. Rogers. — We use water. We have used oil, but the cost of leakage on it would make it undesirable. The radiators themselves are exposed in this room, and there never has been any question about freezing. Probably the winter before last was about as severe a winter as is likely to come, and they stood that test.

Mr. Metcalf. — There is one further question I would like to ask Mr. Farnham, Mr. Rogers and others who have had experience, and that is as to what they consider the practical limit in size of the centrifugal pump which can be used in pumping sewage. In this example at Newton Upper Falls which has been brought to our attention they are using so small a pump

as 2.5 in. I have always been afraid of these very small centrifugal pumps for this sort of service, and I am surprised that they have had no more trouble with clogging of the pump than is reported. The designing of screens for a plant of this kind which will satisfactorily care for the waste which gets into our sewers is troublesome and difficult. My own experience with the basket screen has been very unfavorable. The only satisfactory screen I have had anything to do with has been one made of slats and not a basket weave. Even the slats are not altogether satisfactory, because, as many of you have doubtless noticed, a rag or a towel will go up against the screen, flap there for a little while, gradually weave itself into a little tight roll and slip through the screen with an opening of anything over three fourths of an inch. I have seen them go through the screen and clog the pump several times. In the case of the larger centrifugal pumps, of course, such substances will readily pass through. But I wonder at these works not having trouble with as small a pump as 2.5 in.

MR. FARNHAM. — I presume that Mr. Rogers can give more information about the smallest size than I can. I believe there are smaller pumps than ours in use. I haven't any hesitation in saying of the 2.5-in. pump that it has done the work splendidly. The only trouble we had was with waste, and this before we put the screens in and before we knew we were going to get so much. The only way I can explain the satisfactory operation of the basket screen is, that the waste being heavier, undoubtedly settles down and collects in the basket, so that the basket acts as a sump for collecting a large part of the waste. The mesh is very soon stopped up with paper and sewage overflows from the tops, but the pump throws all other substances out. The trouble from sand occurred only once or twice and was probably due to lack of care in management. That trouble had not developed and we did not operate to prevent it. Had we operated two pumps alternately, probably the sand would not have caked in hard enough to make trouble. It pumped up through one pump all right and settled back against the other pump. The sand is the kind they use for molds in the foundry and it cakes in very hard. The trouble occurred once or twice, and as soon as we discovered what it was it was remedied by a little more care in the management of the plant.

MR. METCALF. — Is there any trouble in cleaning out those screens?

MR. FARNHAM. — I never go there. One of Mr. Ross's men

is detailed to do that work. He is a man of the flushing gang who is not afraid to get his hands dirty. He picks up the waste with a hook, the other matter is thrown into the bottom of the well, with a broom he sweeps it down toward the center of the well and the pump is started. He separates the waste from the other matter and in the course of two or three weeks collects a bushel of it.

Mr. Rogers. — I can add a word of testimony to what Mr. Farnham has said in reply to Mr. Metcalf's question. At Dana Hall they are using a 2-in. pump. The sewage handled there is from a private school and undoubtedly does not contain as much of this heavy waste matter as ordinary municipal sewage would. But the size of the pump at Dana Hall School was selected, not because that size of pump would deliver that quantity of water most efficiently, but because it was considered the smallest desirable size to attempt to use in handling that class of material. It is cheaper to add 1 h.p. to the power of operation than to have any trouble with clogging, and that is about what we have done there. In three and one-half or four years of operation I have heard of no difficulty, and I think the plant has required no undue amount of cleaning.

Mr. Bertram Brewer. — We are building now a plant at Waltham very similar to those described this evening. I don't know that I can add much to the views expressed here except to say that I was very much interested in Mr. Farnham's paper and I think it is entitled to a very careful reading because he is the man who put the plant up and he has to live in the city where it is being run, and he speaks from experience. Our plant in Waltham consists of an electrically-driven vertical motor and vertical pump. The head which we use to pump against is something like 40 ft. We have 2 units — two 5-in. pumps and two 15 h.p. motors, alternating current.

I have found in designing an isolated plant to work automatically there are many difficulties to overcome. For instance, this question of cotton waste, and the necessity for screening. In the Worcester plant, in a large main, where there is a considerable quantity of sewage, a screen was used at first but got out of order, has never been repaired and is not needed. This is not always so. In my own city of Waltham, the watch factory has pumped sewage into the mains for a good many years and has had a hard experience in evolving an automatic plant for that place; so much so that some of our aldermen, who are employed at the watch factory, did not think it was possible to pump sewage

automatically by electrical motors. The watch factory had trouble with waste and still more trouble with air in the pump at starting, owing to the fact that it was placed at the top rather than at the bottom of the well. Mr. Farnham spoke of trouble with waste and sand, and I think those are two things to be looked out for.

The pumps should be placed at the bottom of the well, in a dry pit, with the entrance to the suction pipe, which should be very short, so located that all the harder materials will be frequently stirred up and constantly removed. A long suction gives an opportunity for the harder materials to accumulate.

I have seen the Hudson plant in operation at two different times. There the pumps were placed in a pit by themselves so they could be gotten at at all times; but, when I have seen the plant, the pumps have been purposely submerged in water. I found that there was great trouble with the stuffing boxes and that the pumps leak and have always given trouble, so that the pump pit is kept full of water. Many of its advantages are thereby done away with. I don't know what steps have been taken in more recent plants to overcome this difficulty. I know in my own case it was suggested to me by the manufacturer that he cast a sleeve around these glands which will provide for submerging them alone.

Another problem is connected with the apparatus for starting the motors automatically. In Waltham we have to buy our current and expect to have a special wire in our station to serve our purposes. I have found it very hard to get a reliable automatic starting device for an automatic alternating current motor. I have investigated three: the Westinghouse starter, the Cutler Hammer and one which is manufactured by the General Electric Company. The one used in Hudson is manufactured by the last-named company. As has already been stated this evening, a circuit breaker with time limit relay to take care of an extended overloading of the motor is used in Hudson. The electrician who has charge of the plant informed me, however, that this part of the apparatus was so delicate and so easily affected by temperature changes that it was difficult to keep it in working order.

One of the essential features of the Cutler-Hammer autostarter is the use of water under pressure from the city mains. This necessitates a warm pump house, and, in an isolated plant, a considerable item of expense. Other starters require that some of their mechanism should be immersed in oil, and as a consequence more or less heat is required to keep the oil from congealing.

There are many interesting and important details in connection with the designing of small automatic sewage pumping plants yet to be satisfactorily worked out. The more isolated the plant, the more difficult is the problem. It must be operated with intelligent care and, what is more, by one who is interested in its success.

Mr. M. N. Baker. — I should like to mention one thing that might be worthy of recollection when we develop a little further in the disposal of municipal waste, and that is this: In Great Britain there are many municipal refuse destructors operated at very high temperatures. These destructors are invariably connected with steam boilers, the steam from which is utilized for sewage or water-works pumping, or for electrical supply — sometimes lighting and sometimes electric traction. An English engineer who was talking with me only last week spoke of an installation where the heat from the refuse destructor was being used to pump sewage to an elevation of 300 ft. At a sewage pumping station at Watford, England, which I visited three years ago, steam from the destructor boilers had just been substituted for coal-raised steam. In New England, unfortunately, although much progress has been made in water supply and sewage disposal matters, there has been but little advance in the disposal of municipal refuse. Where any attempt at burning the refuse has been made the result has generally been unsatisfactory. Elsewhere in the United States more has been attempted, but the results have been about the same. I am sure that in the future we are going to see some experimental work on this line. The Borough of Richmond, New York City, now has under consideration bids for a refuse destructor of the British type from representatives of two of the leading English companies. [The contract was subsequently awarded to one of these companies.] Provision is made for the utilization of heat from the burning of mixed refuse; that is, garbage, rubbish, papers, etc., and the ashes. A report has just been made to the city of East Orange on the possibility of combining a refuse destructor with the proposed installation of a municipal electric lighting plant. Although it may be some time in the future before much is done towards utilizing heat from American refuse destructors to pump sewage, it is worth while to have the possibility under consideration. For the present, such a plan would seem to be most feasible where sewage pumping is required for a relatively small portion of a city only, thus insuring a plentiful supply of refuse to do all the pumping. Such districts, and especially the sewer outfall therefrom, are likely to be in outlying sections where

a refuse destructor would be least objectionable. Moreover, the haul of the loaded refuse carts would, in such cases, be downgrade.

Mr. Andrew J. Gavett (*by letter*). — It is proposed to install a small pumping plant at Plainfield this spring. The proposed apparatus will be furnished by the Ingersoll-Rand Company, of New York, through Warren B. Travell, whose proposal was based on the Ingersoll-Rand outfit.

The Ingersoll-Rand Company proposes to furnish and install, with the necessary foundations, the following apparatus, which will include the necessary valves to enable either pump to be cut off from the system for purposes of inspection or repair without interfering with the operation of the other pump:

Two 10 by 6 Ingersoll-Rand class " E " compressors.

Two 7.5-h.p. Wagner motors, equipped with Cutler-Hammer automatic stopping and starting device, with float switch which will operate to start and stop the compressors according to the level of sewage in the float tank.

One Fairbanks-Morse gasoline engine for operating the compressors in the event of failure of the electric current.

One 42-in. by 8-ft. air receiver.

Two duplex displacement pumps or ejectors, to be operated by air supplied by the air compressors.

The plant is guaranteed to have a capacity sufficient to handle 250 000 gal. in 16 hr. against a static head of 13 ft., through an 8-in. force main 2 500 ft. long, and when operated by electric motors to be automatic in operation, requiring only such attention as is necessary to keep the machinery properly lubricated and in working condition.

The Ingersoll-Rand Company proposes to use pneumatic displacement pumps manufactured by the Latta-Martin Pump Company, of Hickory, N. C.

The price for pumping plant as described is $4 655. This does not include the concrete operating chamber.

In the event of failure of the electric current the belt is to be transferred by hand from motor to gas engine, an electric alarm being given by the rise of the sewage above a determined point.

The proposed pumping plant will provide for one of several sections of the city lying too low to be drained by gravity to the disposal works.

The main sewer may be used as a storage reservoir up to a capacity of 8 000 gal.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the Journal.]

CONCRETE PILES.

By Charles R. Gow, Member of the Boston Society of Civil Engineers.

[Read before the Society, May 15, 1907.]

The speaker can hardly treat of this subject as a specialist, since concrete pile construction has constituted but a comparatively small portion of his work and has been adopted and applied as much from necessity as from choice. From time to time, in the course of our business, we have been requested to suggest ways and means for overcoming foundation difficulties and have found it convenient in many cases to recommend some type of concrete pile construction to meet the conditions.

I am convinced, in the light of our experience, that concrete piles have come to stay and must be accepted by the engineering fraternity as a permanent addition to the list of foundation expedients. Like all innovations, however, it is susceptible of being overdone through excessive enthusiasm and the usual desire to try something new. Already there is evidence of this in a few cases that have come under the speaker's observation, when the new type has been used at a sacrifice of economy without any compensating advantage. In other cases a misunderstanding of the possibilities of these piles, or a lack of knowledge of their dangers, has led to serious results in construction. It will be well, therefore, for engineers who contemplate using this construction, to thoroughly familiarize themselves with the entire subject and not take too much for granted.

Economic considerations usually demand that a concrete pile shall be capable of replacing at least three or four wooden piles. To do this it must carry safely a load of approximately thirty tons. It must be borne in mind that the ground under and around the pile must ultimately carry this load, and since there is a limit to the carrying capacity of any soil, there must also be a limit to the load we can concentrate on one pile of ordinary section. For the subsoil conditions in this locality, the above load of thirty tons is probably a maximum safe limit.

During the past few years a variety of methods have been devised for making and driving concrete piles. Each method

has introduced novel and ingenious ideas of considerable merit, but few, if any, have been free from objectionable features. It is a healthy sign that improvements are being continually made by the various inventors tending toward the elimination of these undesirable features. It is probably sufficient, for the present, to feel that even in the infancy of the subject we have our choice of several methods, any of which is capable of considerable possibilities if intelligently handled. I would especially emphasize this point, however: when the demands on a small concrete section are so severe, as in this case, a superior excellence of construction is absolutely essential. Other things being equal, therefore, the method which seems to guarantee this result with the minimum risk is the most desirable. Since none of the methods in present use entirely eliminates the element of risk, there is always a chance for intelligent study by the engineer before finally making his choice. For the reasons stated, our firm has made it a practice not to adhere to any one method but to recommend different methods for different conditions, as our judgment dictated.

In general, concrete pile construction may be divided into two classes, viz., piles built in place and those cast and driven. Both methods possess certain advantages as well as limitations. In the first class, the inaccessibility of the space where concrete is being placed, and the uncertainty as to what takes place during and after placing the concrete, is apt to leave some doubt as to its final sufficiency. In the second class, while the quality of construction is apparent with even superficial inspection, the possible danger during driving is extremely problematic.

As being of possible interest to the Society, I will enumerate some of the methods which have been used by us, together with the reasons for their adoption. Our first experience with concrete piles occurred about five years ago. An outbreak of quicksand had occurred in the basement of a mill building of rather heavy construction and in a few days had so damaged one corner of the building as to necessitate tearing it down. The remaining walls were threatened and indicated some settlement. Borings developed the fact that the building rested upon a thin stratum of hard pan overlying a bed of quicksand 25 ft. in depth. Below the quicksand was a stratum of very coarse gravel charged with water under a head, the elevation of which was 14 ft. above the basement floor. It was decided to drive piles to the gravel in two rows, one inside and one outside the line of the walls and to support the wall on needles capping the piles. Driving wooden

piles was out of the question, as the headroom required for the driving would necessitate removing the floors. Also the heavy jar produced by the driving would disturb the ground and tend to further settle the walls. At our suggestion the following method was adopted:

Eight-inch wrought-iron pipe in 5-ft. lengths was tapped down with a light hammer, the successive lengths being coupled together until the bottom section rested in the gravel. The pipe was then washed out with a water jet, thus removing all the quicksand. A 1-in. pipe perforated for 2 ft. on the lower end was then inserted and driven into the gravel for about 3 ft. Grout was forced into the 1-in. pipe, the intention being to form a ball of grouted gravel under the bottom of the 8-in. pipe and also to seal the bottom of the pipe against the inflow of water. After the grout had set, the 8-in. pipe was pumped out and filled with concrete. Two of these piles were subsequently used as a support from which to jack up some floors which had settled, and an estimated total pressure of 70 tons, or 35 tons on each pile, was applied without any measurable settlement of the piles. This method has since been used in a variety of cases, sometimes with slight modification. Its great disadvantage lies in the cost due to loss of pipe. On the other hand, it forms an exceedingly strong column, and, provided the foundation under it was sufficient, would carry tremendous loads. Such piles are commonly used in and around New York City in underpinning work, and the engineering press recently described their use in a new downtown building in that city, the pipes being 12 in. in diameter sunk 90 ft. to ledge and figured for as high as 116 tons each. In this case a reinforcement of round bars of large section was used, the steel being figured in compression.

A short time after this experience we were confronted with the following problem: A large brick building in the North End of this city had been originally constructed with the outer walls supported on piles and the inner partition walls resting on mudsills. These interior walls settled until the floors were in an unsafe condition and repairs imperative. In this case the underlying soil was a 15-ft. layer of black mud and filling overlying blue clay. Old walls and timbers in the filling admitted tide water freely, so that an open excavation would require steam pumping, with the consequent danger of removing much of the mud, thus producing further settlements. The pipe method as used in the former occasion was inapplicable, since the clay bottom would take no grout and the piles would have a bearing

equal only to the area of the pipes. Figured on this basis, an excessive number of pipes would be required. This condition led to the invention of our chambering system, shown by Fig. 1. Eight-inch pipes are driven as before about 1 ft. into the clay and washed out. The washout drill is allowed to excavate for a further distance of 2.5 ft. below the bottom of the pipes and is then withdrawn. An expanding cutter of simple construction is lowered to the bottom of the pipe so as to rest in the clay below its bottom. By revolving the cutter, a circular chamber is formed 3 ft. in diameter on the base, and in shape approximately a frustum of a cone. The chamber and pipe are then filled with concrete. The result is a concrete shaft resting on an enlarged base. While we usually recommend leaving the pipe in, we have also on many occasions withdrawn the pipe as the concrete filling progressed. This system has been found particularly useful in inside work, although we have employed it in many cases in the open where it seemed to offer advantages.

Some time later the use of these chambered piles was suggested in the building underpinning operations connected with the construction of the Washington Street tunnel. It was our impression, however, that they were unsuited for this purpose since they would be subjected to lateral pressure during the period of adjacent excavation. As the practicability of the washout method is limited to pipe sizes up to about 14 in. in diameter, a very small section would be available to resist this lateral thrust. To meet this requirement, we abandoned the chambered pipe system in favor of the caisson method, similar to that in common use in Chicago during the past ten years, although at the time the idea was original as far as we were concerned.

By means of this method a pile of any diameter from 3 ft. upward may be constructed in the following manner: A circular excavation of the required diameter is started from the surface by means of pick and shovel. When the excavation has progressed a few feet in depth, a cylindrical steel lining in two halves is inserted and the halves are bolted together. This forms a lining which maintains the shape of the hole and protects the workman. As excavation proceeds, additional layers of steel lining are lowered to the workman, who inserts them under the first lengths and bolts them together. The sections of linings, being in two halves, are easily passed up and down through the shaft. When excavation reaches clay or other firm material, a chamber may be excavated to any reasonable diameter. The whole excavation may then be filled with concrete, the steel lining

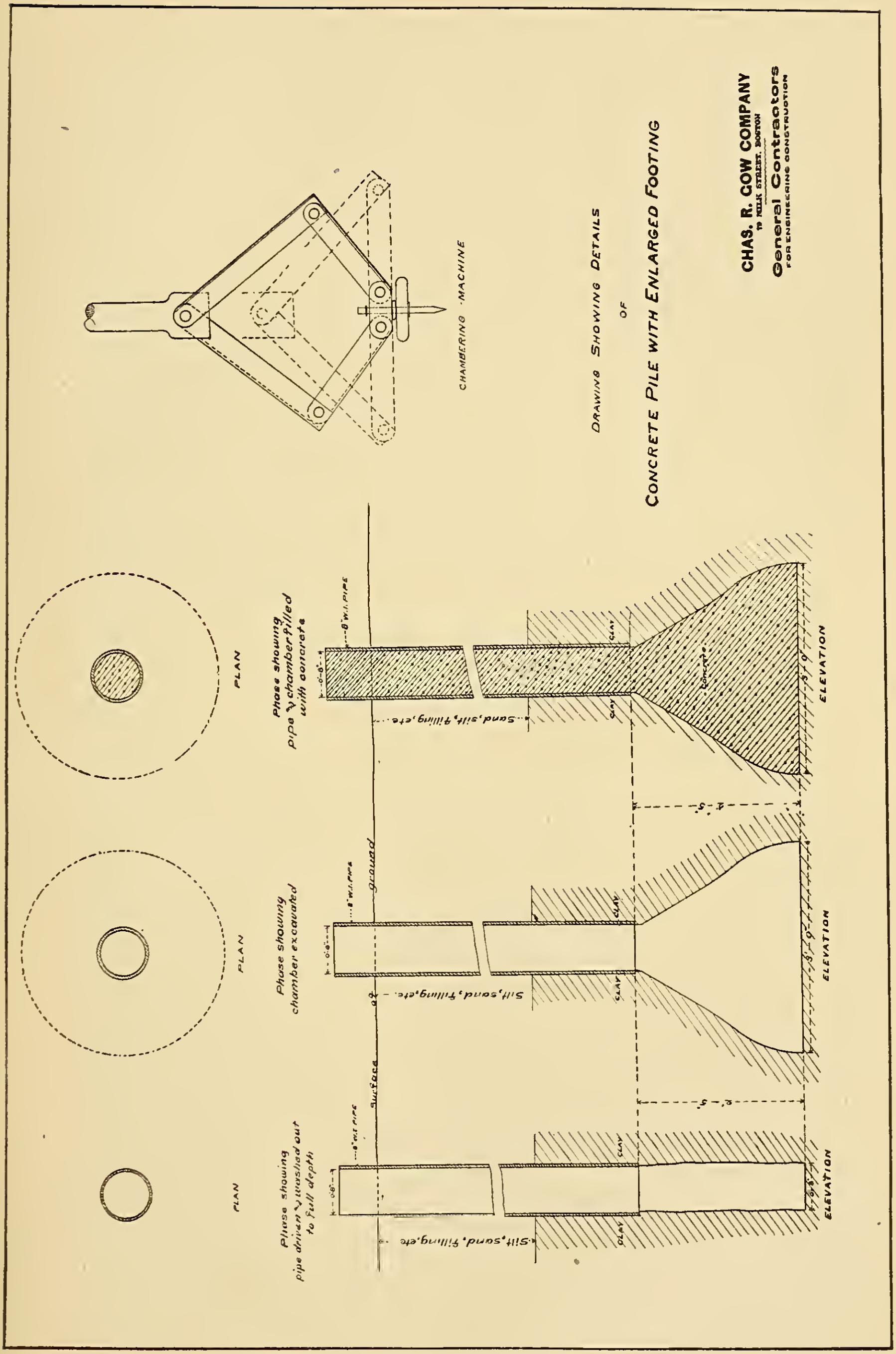

CHAS. R. COW COMPANY
General Contractors
FOR ENGINEERING CONSTRUCTION
DRAWING SHOWING DETAILS
OF
CONCRETE PILE WITH ENLARGED FOOTING
CHAMBERING MACHINE
PLAN
PLAN
PLAN
Phase showing pipe & chamber filled with concrete
Phase showing chamber excavated
Phase showing pipe driven & washed out to full depth
ground surface
Sand, silt, filling, etc.
Silt, sand, filling, etc.
Silt, sand, filling, etc.
CLAY
Concrete
ELEVATION
ELEVATION
ELEVATION

FIG. 1.

being removed, section by section, as the concrete rises in the shaft. In sections where the ground penetrated is too unstable to stand at all, as in the case of running sand, the lining is made of a series of whole cylinders about 6 ft. long each, but of varying diameters to allow each successive length to telescope through the previous section and to penetrate 6 ft. in advance of it. This type of pile has proved remarkably economical and practical for heavy concentrated loads. We have on one occasion constructed a 15-ft. diameter chamber under a 3-ft. shaft excavation. The required diameter of the chamber, of course, depends upon the total load to be carried and the unit-bearing capacity of the soil. A caisson pile having a 3-ft. diameter shaft and a 9-ft. diameter chamber in good clay is safe for a load of 250 tons. The chief advantages are the minimum of excavation required, absence of concrete forms, and the consequent increase of progress.

By far the most interesting case of concrete pile work we have yet handled is that of the Milton car barn foundation for the Boston Elevated Railway, on which we are now working. The site of the work, covering a little less than an acre, is one of the most peculiar ground formations ever met with in our experience. Surrounded on all sides by ledge, the lot itself is a deep deposit of semi-fluid mud and quicksand extending to a maximum depth of 40 ft. The mud and sand are interspersed with what appear to be floating masses of hard pan, and at times beds of gravel overlying the quicksand are encountered. There seems to be no particular order or relation between the different classes of ground, and to further complicate matters the ledge bottom itself is so irregular that variations of 10 ft. in depth sometimes occur in a few feet distance. As the entire ground is thoroughly saturated with water, wooden piles would have been sufficient except for the possibility of future drainage if the ledge divide was ever penetrated. Concrete piles built in place were considered dangerous on account of the extreme depth and the unstable surrounding soil. The only alternative was the driving of cast piles, and this was the system finally adopted. Soundings were made at the location of each pile. A 0.5-in. gas pipe was coupled to a water hose fed by city pressure and jetted down to ledge. In this manner the exact depth from the surface of the ledge was determined for each location and a pile cast and numbered to correspond.

The proposed building covers an area of approximately 37 000 sq. ft.; 414 piles are required, ranging in length from 1.5 to 40 ft. All piles up to 6 ft. are built in place in a wooden

Fig. 2. Group of Cast Piles Ready to be Driven.

Fig. 3. Section of Finished Floor showing Concrete Pedestals over Piles.

Fig. 4. Cast Piles 36 Feet Long, being Handled by Derrick Preparatory to Driving.

form. A low wall of concrete capping the outside lines of piles supports the building walls, while interior loads are, for the most part, carried on columns resting on a single pile. Each interior pile is capped with a block of concrete 2 ft. square, in the top of which is set a dowel to take the wooden column. To prevent any lateral motion in the soft mud, the original plans contemplated the use of concrete tie beams in four directions. Owing to the difficulty of trenching for the beams in the semi-fluid mud, and the absence of any foundation on which to lay the concrete, this feature of the construction was changed at our request to the use of a 6-in. slab of concrete covering the entire lot and surrounding the pile heads. This slab rests upon a 6-in. bed of cinders overlying the mud. It is reinforced with poultry netting crossed in two directions. As the slab floats on the mud, precautions were taken to break its bond around the piles and against the walls by the insertion of tarred paper in order that it might settle evenly if at all.

The piles were cast with a square section 13 in. on a side, and since they were to act as bearing piles no taper was given them. The mixture was a 1 : 2.5 : 4 concrete. Clinton electrically welded wire cloth was adopted as a reinforcement, having 0.25 in. longitudinal wires 3 in. on centers. This reinforcement was bent to such shape as to make a continuous reinforcement 2 in. inside the face of the piles on all four sides. A line of tin speaking tube 1.5 in. in diameter was built in at the center of the pile to admit water for jetting purposes. This tube was stopped about 10 in. from the head of the pile and, by means of an elbow and threaded nipple, projected through the side of the pile to allow of attaching the pressure hose. The piles are handled with guyed derricks and inserted in a timber guiding frame containing a pair of driving gins. As soon as it is properly centered the jetting hose is attached to the nipple, and water, supplied by a steam pump at 100-lb. pressure, is forced through the interior tube and out of the bottom of the pile. It has sometimes been found expeditious to churn the pile up and down during sinking by means of the derrick. This action appears to thoroughly loosen the surrounding ground and allows a freer escape of the material below the pile.

As stated, at intervals all over the lot thin layers of hard pan are encountered, apparently floating in the mud and sand. It has been necessary to drive the pile through these masses when encountered. Much apprehension was felt as to the possible damage which might result from the driving of these piles. A

wooden follower has been used, resting on the pile head, and a 2 800-lb. hammer dropped from as high as 20 ft. has failed to produce any apparent injury. In the case of one pile the sounding pipe used in determining the necessary length of pile had penetrated a narrow crevice between two bowlders and the pile was cast to the length so found. Upon attempting to drive this pile, the space between the two bowlders proved to be too small to admit it. Not knowing what the obstruction was, the foreman attempted to drive through it. Three hundred blows of the 2 800-lb. hammer dropping 12 ft. were given without appreciable penetration, and rather than cut off and waste about 6 ft. of undriven pile, it was determined to pull the pile out and replace it with a shorter one. Upon withdrawing the pile, it was found to be perfectly sound and uninjured, except that the point had been slightly worn away on each side where it had rested against the two bowlders. Each pile is finally driven until it brings up firmly on the ledge.

The extreme length of many of the piles introduced the serious question of how best to handle them and avoid breakage. It was found that up to 30 ft. in length they could be picked up by the end without producing any undue strains, but when over 30 ft. they almost invariably cracked in the middle. To prevent this action, four angle irons were at first used strapped to the four corners of the pile by means of iron clamps. This method was effective, but the time required in placing and removing the irons rendered it impracticable. A simpler device was finally adopted which has allowed the handling of piles up to 40 ft. in length without damage. A long chain is used, one end being wrapped around the pile near the center, while the other end is similarly wrapped near the top end; the hook of the hoisting fall is hooked into the long loop of the chain, and as the pile is hoisted the hook slips along the chain toward the top as the pile is gradually upended. By this means, while the pile is in a horizontal position, the strain is applied almost equally at the two points of attachment and prevents undue stresses at the center of length. Once in an upright position, of course, no further precautions of this nature are necessary.

The time required in driving a pile depends entirely upon the nature of the ground penetrated. A 35-ft. pile has been put down in 9 minutes, while piles one half that length have sometimes required 3 hours.

In some cases difficulty was encountered in maintaining the pile in exact location, due to underground obstruction deflecting

its course. The maximum variation of this nature thus far noticed has been about 6 in., and fortunately has occurred under walls where the objection is slight as compared with its possible occurrence under columns, in which case a single pile supports the concentrated load.

This work was started late in November of last year. The early and severe freezing spells of that time caught us unprepared, with the result that about 75 piles were badly frozen. A thick covering of hay proved inefficient, as did also lines of steam pipes under the hay, spaced 10 ft. apart. Many of the piles were frozen before taking an initial set, and all of them before final set. Work on casting was then suspended until a shed could be constructed in which to cast the remainder. All attempts at protecting the frozen piles were abandoned and they were left to their fate, suffering alternate freezing and thawing throughout the winter. Late in January one of these piles was sent to the Watertown arsenal, thawed out, and immediately thereafter tested for crushing strength. It failed at 60 tons, or 710 lb. per sq. in. This test was deemed sufficient by the building department to warrant the condemning of the entire lot of frozen piles, but at our request a second sample was selected at random from the frozen lot and, accompanied by one of equal length taken from the lot cast under cover, was sent to the arsenal for a second test. This time the frozen pile was allowed to remain in a warm room after thawing for about 4 weeks before testing. It failed at 236 tons, or 2 800 lb. per square inch. The unfrozen sample failed at 241 tons, or 2 852 lb. per square inch. It would appear, therefore, that the frozen pile recovered practically all of its strength as soon as the freezing action was permanently removed. All of this lot of piles have since been driven. In a few cases the extreme ends of the frozen piles appeared to be slightly disintegrated. In such cases we cut off the ends exposing the reinforcement and recast them. Some of the piles thus repaired were driven within a week without injury to the new heads. In the case of one of these piles the head was shattered when the pile was within 3 ft. of grade. A new head was cast in place, the pile allowed to stand for a week, and it was then successfully driven to grade.

Some of the piles in this work have been successfully driven through material that the 0.5-in. sounding jet penetrated with the greatest difficulty, and if tapered they could probably be driven through any material that a wooden pile would penetrate.

As the work was suspended for the winter after casting the piles, no information was obtained as to how long after casting

the piles could be handled and driven. It is probable that if cast in warm weather they could be handled in two weeks without injury.

As this work was the first of its kind in this vicinity, there was no available previous experience to guide us. Consequently, as might have been expected, mistakes were made in many details.

With the idea of saving expense for forms, the ground was leveled off and covered with tarred paper on which was placed the side forms for each pile. The soil was so soft, however, that it settled under the load of the green concrete from one to three inches, resulting in a great waste of concrete and adding materially to the weight of pile to be handled.

These piles, if built as designed, weigh 175 lb. per linear foot, and the longest ones, therefore, weigh about 3.5 tons. It may be readily understood that the handling of such a heavy load requires extreme care at all stages of the work. Owing to the fact that our piles were cast in many instances at a considerable distance from the point where they were to be driven, much time was lost in moving them to the driver. Another time we should attempt to so lay out our work as to bring each pile within easy reach of the driving apparatus which was to drive it.

In the case of friction piles, some knowledge will be necessary as to the ability of concrete piles to penetrate different soils. Otherwise the lengths will be very indeterminate, and much waste of material and labor must result. For such piles a slight taper will probably assist the driving through firm material.

One important point to be considered in cases where the water jet method is contemplated is the displacement of soil which takes place owing to the jet action. This displacement in such soil as mud and fine sand appears to be something greater than the actual contents of the pile. This probably does not signify that voids have been left in the ground below, but rather that the disturbed soil has been altered in density, and a resulting shrinkage or subsidence may occur in the future as the material gradually returns to its original condition. An interesting feature of the Milton work in this connection has been the tendency many times for the water from the jet to reappear, not around the pile being driven, but in some cases around some other pile already driven, or perhaps through some old test pipe hole from fifty to one hundred feet away. Meanwhile the ground in the vicinity of driving has risen from one to one and one-half feet in elevation.

In conclusion I will say, it is my belief that cast concrete piles are a success in the same sense that all types of concrete piles are successful, and that they compare favorably in cost with those built in place. As before stated, I believe that neither type is universal in its application; that both have their limitations, and that there still remains a vast field for the continued use of wooden piles.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the JOURNAL.]

THE SIMPLEX SYSTEM OF CONCRETE PILING.

By Thos. MacKellar, Member of the Boston Society of Civil Engineers.

[Read before the Society, May 15, 1907.]

Among the various methods employed nowadays in the construction of foundations for buildings and structures of all kinds, concrete piles are beginning to play such a large and important part that they must be recognized as one of the standard methods of foundation construction. While it is known that so far back as the early lake dwellers of Europe wooden piles have been used for foundations or to keep foundations in place, it is not until comparatively recently that concrete piles have been used successfully. In the search for some material more lasting and durable than wood with which to build up a pile, engineers in France first conceived the idea of driving down a form of wood or some other material, withdrawing it and filling the resulting hole with wet sand thoroughly rammed into place, thereby causing the whole ground to be highly compressed and capable of sustaining large loads, forming a foundation of what is known as sand piles. This might be considered as the first intermediate step between wooden piles and concrete piles.

The continued and increasing demand for some permanent form of pile that would resist the destructive action of air and water, as well as other enemies, brought many minds to bear on the subject. About thirty years ago a patent was taken out in this country for producing concrete piles by driving down a solid steel tapered form, withdrawing it, and filling the resulting hole with concrete.

This was not a commercial success, however, as in most cases the ground tended to collapse upon withdrawing the form, making it impossible to properly fill the hole with concrete. At the Paris Exposition concrete piles 36 in. in diameter were formed by dropping a heavy conical plumb-bob weighing 10 000 lb. from a height of 30 ft. This process was repeated until a hole about 30 ft. deep had been formed, which was then filled with concrete. This was a slow and expensive process and worked successfully only in ground that was moderately hard. Little further was heard of it.

It remained for the French engineer, Hennebique, to produce the first concrete pile that was put into actual use and that proved to possess commercial value. His method was to cast a strongly reinforced concrete pile in a mold, allowing it to set hard, and then driving it in the same manner as a wooden pile. This was a great improvement over anything that had yet been brought out, but still possessed certain disadvantages. To avoid the shattering effect on the concrete of direct impact it was necessary to use a special drivehead, the interior of which was filled with sawdust to soften the force of the blows. It was necessary to cast a large number of these piles beforehand, as it would be scarcely safe to handle them under less than thirty days set, and a large space was necessary for their proper handling and shipping. Besides Hennebique's pile, there are a number of others which are molded, allowed to set, and then driven or jetted down.

The next type of concrete pile was produced by Raymond, who used a collapsible tapered steel driving form, around which was tightly fitted a thin sheet-iron shell of about No. 20 gage. The combined form and shell were driven to the required depth, the form was collapsed and withdrawn, leaving the shell in place in the hole, which was then filled with concrete. The resulting pile consisted of a concrete core surrounded by an iron shell, which in time rusted away.

The Simplex concrete pile was the next to enter the field, and will form the subject matter of this paper. First adopted by Capt. J. S. Sewell, Corps of Engineers, U. S. A., for the foundations of several buildings at the Washington barracks four years ago, its use has since become so widespread and successful that at present it is being specified by several of the largest railroads and numerous architects and engineers throughout the country. The first idea brought forth was to drive a wooden form to the required depth, withdraw it, and fill the hole with concrete. This method was found to be unsatisfactory, due to the tendency of the sides of the hole to collapse upon withdrawing the form, and was soon discarded. A hollow steel form was then tried, on the bottom of which was placed a molded concrete point. This form, resting on a shoulder molded around the top of the point, was driven down to the required depth, and then withdrawn, the point remaining at the bottom of the hole, and the necessary amount of plastic concrete was filled into the hole simultaneously with the withdrawal of the form.

This method was found to work in a perfectly satisfactory

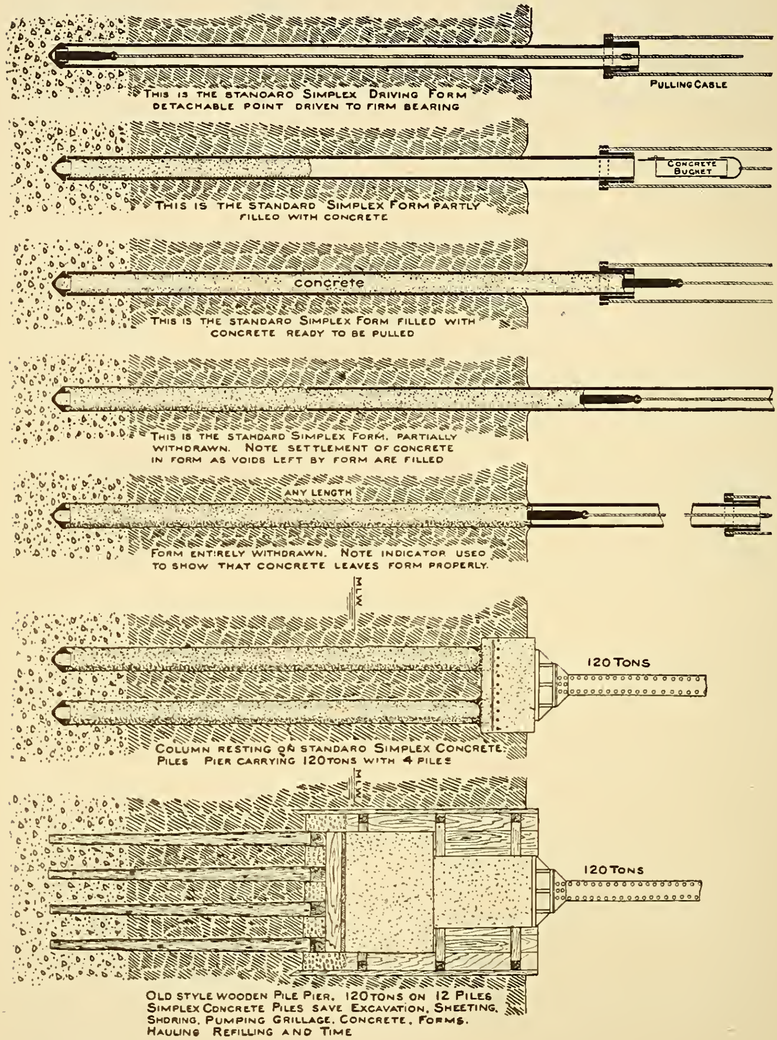
manner and to give good results, but still showed that there was room for improvement. It was necessary to cast a large number of the concrete points in advance in order to allow them to attain a hard set before driving on them, and this necessitated a large storage place, with capacities for handling and shipping the points. Also there was the liability of the concrete's shattering under the repeated heavy blows of the hammer, thereby producing an imperfect pile. Finally it was decided to use cast-iron shell points, for the reasons that they were less expensive, easier to handle, required less storage space; in fact, being shipped direct from the foundry to the work, would stand a great deal more battering than concrete, and, being very blunt, would furnish an excellent end-bearing. Although this loose point method of driving the piles was the most successful that had yet been tried, it did not seem right to have to leave a cast-iron point at the bottom of each pile, practically amounting to throwing away so much money every time a point was used, and increasing the cost of the finished pile. Finally Mr. Constantine Shuman, chief engineer of the Simplex Concrete Piling Company, conceived of the idea of attaching, by means of a cast-steel sleeve, to the lower end of the driving form, two cast-steel jaws in such a manner as to allow them to swing freely.

These jaws are segments of a true cylinder the same size as the sleeve, formed by two planes, one cutting in at approximately 30 degrees to the axis and the other at right angles to the first and intersecting a little short of the axis. When brought together they form a sort of a clam-shell point, perfectly tight and well adapted for penetrating the ground. When hanging open, they form a true cylinder of the full size of the pipe above and give a straight and unobstructed chute for the passage of the concrete. In practice the jaws are closed and kept that way by the pressure of the earth against them in driving, and the form is driven down to the required depth. Upon withdrawing the form the jaws open of their own weight and permit the passage of the concrete past them. To obtain perfectly satisfactory results by this method, the ground must be firm and compact, as any back pressure in the ground tends to partly close the jaws, thereby reducing the diameter of the pile and rendering it imperfect. Owing to this the use of the "alligator point form," as it is called because of its resemblance to a giant saurian, has never become general but is used only in a few localities where ground conditions favor it. This meant a return to the loose points, which is the method in general use to-day by all the companies operating under the Simplex patents.

The apparatus employed in driving Simplex piles is built along the same lines as the ordinary wooden pile driver. Owing to the nature of the work it is called upon to perform, however, it is much heavier and more complicated, inasmuch as it has to withdraw the form after it has been driven into the ground the necessary distance, something which the wooden pile driver does not have to do. Everything about the whole apparatus is made of as rugged and simple a nature as economy in cost and handling will permit. The 3 300-lb. hammer strikes on a hickory block set in a steel drivehead which rests on top of the driving form. The wooden block is found necessary to lessen the upsetting action of the powerful blows of the hammer on the top of the form. The driving form is made up of a single 40-ft. length of 16-in. diameter steel pipe, 0.75-in. metal, at the top of which is fastened, by means of twenty-four 1-in. csk. rivets, a boiler steel band 0.5 in. thick and 18 in. deep. This band serves the double purpose of reducing the upsetting action on the form due to the hammer, and for use in pulling the form. The form rests on a shoulder at the top of the point and is kept centered by means of a tenon on the point which engages with the inside of the form. The point itself is hollow, 10 in. deep, 16.5 in. in diameter, and has a projected sectional area of 1.4 sq. ft. The form is withdrawn from the ground by means of two 1-in. steel cables fastened to a steel collar, which engages under the reinforcing band at the top of the form. The cables pass in the channel leads on each side, over the head of the driver and down in back to a pair of fivefold steel blocks, the lead-line from which passes to one of the drums on the engine.

In this manner the power of the drum is increased ten times, and it is no uncommon thing to break the pulling cables when the form is in hard ground. To illustrate the force necessary at times to withdraw the form, while on some work in South Boston last fall for the New York, New Haven & Hartford Railroad, on one pile our form struck a heavy timber about 25 ft. below the surface and on being driven through it became wedged in it tightly. Before it was withdrawn, besides our regular pulling rig, we were using a fall of double hemp blocks and two 30-ton jacks. Upon redriving the form it became wedged again, and in spite of the fact that we this time put the two jacks at the end of a lever, which doubled their capacity, and used an extra set of fivefold blocks, the form had finally to be abandoned and left there to take the place of the ordinary pile. Fortunately this is a very rare occurrence.

The general method used at present in driving the Simplex pile is about as follows, being changed slightly to meet varying conditions: The form, resting on a cast-iron point, is driven to hard pan or whatever bearing and penetration are obtainable and



necessary to carry the required load. A heavy weight is then lowered into the form to make sure the point is loose. While the weight is at the bottom of the form a target is placed on its line at the top of the form, the purpose of which will be apparent later. The weight is then withdrawn. Given the length of the pile and

sectional area, it is an easy matter to determine the volume of concrete necessary to fill the hole.

This amount is put into the form by means of a specially designed bottom dump bucket, which permits the concrete to leave it in one mass, reaching its destination with practically no disintegration. It will be noticed that when the full amount of concrete is in the form its surface is considerably above the surface of the ground. This is due to the fact that the thickness of the form occupies considerable space that is to be occupied by the concrete. The weight is now placed on top of the concrete and the form is pulled. The target previously mentioned now becomes useful. As the form is withdrawn the concrete settles down to occupy the space left by the walls of the form. Obviously this settlement should proceed at a uniform rate, and as it is difficult to watch the weight, the target on its line further up is of considerable help. By watching this target in connection with a scale on the leads of the driver, it can be readily told how the concrete in the form is acting. As another check, the target, just as the bottom of the form is leaving the ground, should be level with the top of the form. This would indicate that the necessary amount of concrete has gone into the ground and that, other conditions being all right, the pile is a good one. In some grounds where the head of concrete in the form exerts a greater pressure than the back pressure or resistance of the earth, the concrete will be forced out into the sides of the hole, making the pile of increased diameter at that point and necessitating the use of more concrete to bring the pile up to the required level.

This, of course, is no objection. One great advantage of the loose point method is that in withdrawing the form and placing the concrete the end bearing is in no wise disturbed and you know that you are getting the full advantage of the hard driving and small final penetrations. The presence of water in the soil causes no trouble, as the form is practically watertight under ordinary conditions, and can be made absolutely so if necessary.

Thus driven, the Simplex concrete pile is a rugged, monolithic column, 16 in. in diameter from top to bottom. The concrete, leaving the form, forces itself into intimate contact with the surrounding earth, cementing itself to any rocks, brickbats, or bowlders it may have encountered, and presenting an extremely rough frictional surface to the ground around it. This question of side friction is interesting and is worth considering for a few moments. It is on this side friction that piles depend to carry the greater part of their load, and the value of this friction depends

on the character of the ground. In most instances where piles are necessary the frictional value increases with the depth, so that the ideal pile would be the one which took the best advantage of this and placed small reliance on the upper poor ground. A comparison of the various piles in this respect is interesting and shows clearly how the loads are transmitted to the surrounding ground.

There are on the market at present practically only three styles of piles, — the ordinary wooden piles, the tapered concrete pile, either molded before driving or made in place, and the cylindrical concrete pile.

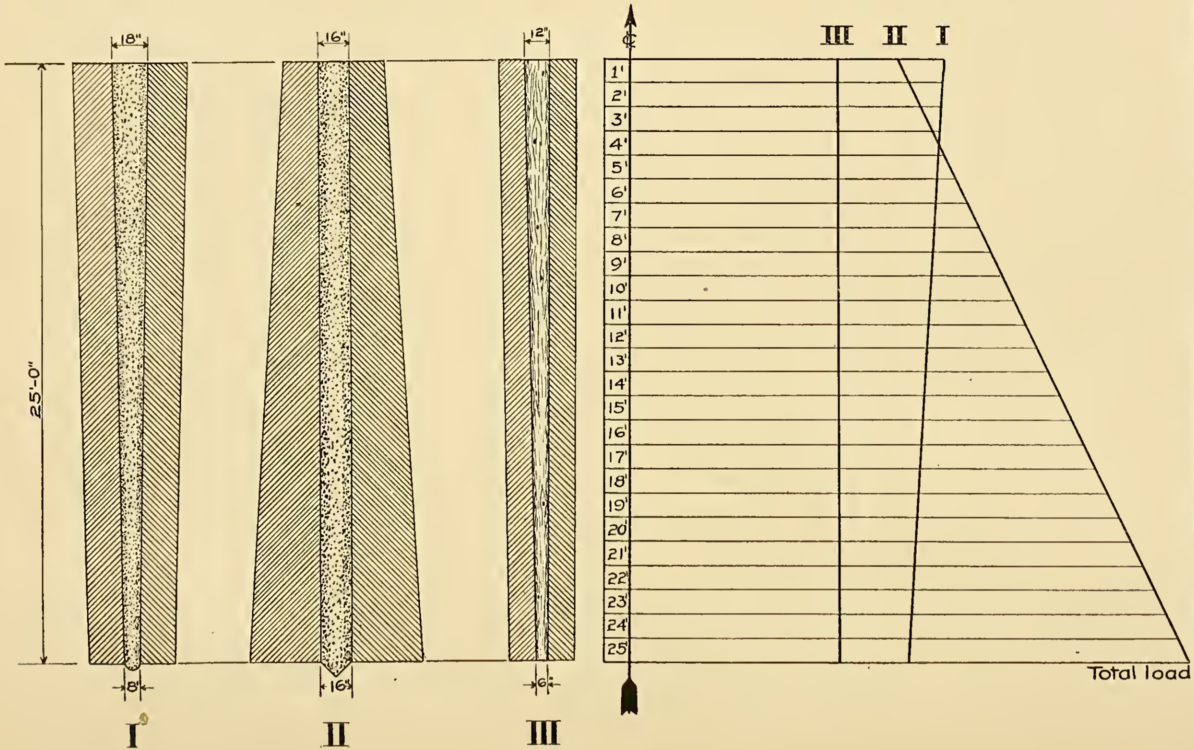
For the purpose of comparing these piles let us assume ground conditions which will bring out the most good points of each system, making the comparison as fair as possible to all concerned. Assume that the ground is of such a firm and compact nature that one square foot of pile surface at the butt of the pile will develop a carrying capacity of 0.35 ton, increasing uniformly to 0.7 ton per square foot of pile surface at the point of the pile. Assume each pile to have been driven 25 ft. into this ground. Also assume the ultimate friction of the concrete and wood against earth to be the same, and neglect the end bearing values of the piles. Then we have the superficial area for one linear foot of pile at the butt and at the point for each pile to be as follows:

Pile.	I.	II.	III.
Butt	4.71	4.2	3.14
Point	2.1	4.2	1.57

Multiplying these areas by the unit loads for the butts and points of the piles and scaling them off as shown on the plate, and connecting the upper points with the lower points, diagrams are obtained which show, not only the total loads carried due to superficial friction by the piles, but also show how the loads are transmitted to the surrounding earth. The diagram shows this more in detail and also shows a table giving the loads carried by each linear foot of pile as scaled from the diagram. The diagram of pile I shows that a slightly greater load is transmitted to the surrounding ground at the butt of the pile than at the point.

In other words, the very reason for the use of piles is defeated by placing over half the load on the poor upper earth. The diagram for pile III shows that the loads are very uniformly distributed to the surrounding ground for the whole length of the

HALF OF DIAGRAM SHOWING CAPACITY OF PILES PER LINEAL FOOT.



Load per lineal foot.			
Foot	I Tons	II Tons	III Tons
1	1.652	1.470	1.100
2	1.640	1.530	1.100
3	1.634	1.590	1.100
4	1.628	1.650	1.100
5	1.620	1.710	1.100
6	1.608	1.770	1.100
7	1.602	1.830	1.100
8	1.594	1.890	1.100
9	1.588	1.954	1.102
10	1.578	2.014	1.102
11	1.572	2.080	1.102
12	1.566	2.140	1.102
13	1.558	2.200	1.102
14	1.552	2.260	1.102
15	1.544	2.320	1.102
16	1.536	2.386	1.102
17	1.530	2.446	1.102
18	1.522	2.508	1.104
19	1.514	2.570	1.104
20	1.506	2.630	1.104
21	1.500	2.690	1.104
22	1.492	2.750	1.104
23	1.486	2.814	1.106
24	1.478	2.876	1.106
25	1.470	2.940	1.106
	38.97	55.018	27.56

pile, which is little better than pile I. The diagram for pile II, however, shows that small reliance has been placed on the carrying capacity of the upper earth, and that by far the greater part of the load is transmitted to the ground around the bottom of the pile. In other words, it shows that as the carrying capacity of the earth increased, the pile placed a greater load on it, thereby developing the power of the ground in a rational and logical manner. Piles I and II place the *greatest load where the earth is weakest, and reduce the load as the soil becomes stronger.* Aside from this it will be noticed, in summing up the loads carried by the various piles per linear foot, that pile III carries the smallest load, pile I next, and that pile II will carry more than twice the load of pile III, and over half again as much as pile I. In all this discussion the end bearing of the piles has been neglected. To look at this point for a moment, it will be noticed that pile I has an end bearing of 0.34 sq. ft., pile II an end bearing of 1.4 sq. ft., and pile III has an end bearing of 0.2 sq. ft., or, in other words, pile II has an end bearing equal to four times that of pile I and seven times that of pile III. Assuming in the soil discussed above that the end bearing will develop 5 tons per square foot, then pile I will develop 1.75 tons, pile II, 7.0 tons, and pile III, 1.0 ton.

The advantages of Simplex concrete piles over wooden piles and other forms of foundation construction under certain conditions are so obvious as to hardly need recounting, but it can do no harm to recall a few of them. Compared with wooden piles, concrete piles possess great durability and are not subject to destruction by rot or the attacks of insects which are so destructive to wood. They can be used in any place where wooden piles can be driven and in a great many places where they cannot. An important point to be noticed is that concrete piles save from 20 per cent. to 80 per cent. of the concrete in the footings, with the attendant necessary excavation, pumping, sheet piling, and so on, because no attention is paid to the water line. In comparison with deep footings or piers, a great saving is made not only in the concrete and excavation, but in many instances considerable time is saved. For instance, a column carrying 120 tons has to be supported and hard pan is 20 ft. below the surface. If the hard pan is good for 5 tons per square foot, then the pier would have to have 25 sq. ft. of area at its base. This would mean the excavation of a hole at least 7 ft. square from top to bottom, with the necessary sheet piling, shoring, and perhaps pumping, and would take a week or ten days to finish. Four Simplex piles would carry the required load, and could be driven in a morning,

after which all that would be necessary would be a capping about 2 ft. deep by about 5 ft. square, the whole operation consuming not more than two days' time.

A unique field for concrete piles is in the foundations of large stacks or water towers. Here they resist the overturning action, not by dead weight, but like the roots of a large tree, gripping the surrounding earth very strongly on account of their extremely rough surface. In France, recently, a reinforced concrete wharf was built, using Simplex concrete piles, heavily reinforced, for the foundations.

Simplex concrete piles were first used in the foundations of a number of buildings at the Washington barracks. As these buildings were rather light it was intended at first to extend the foundations just below the frost line, but the ground being regarded with suspicion, several tests were made, from which it was discovered that the earth was totally incapable of sustaining the required loads. Figures were gotten for installing the foundations by sinking caissons, using heavy concrete piers, wooden piles cut off below low water and by spread footings. These methods were all found to be too expensive, however, and the Simplex system was finally adopted as being the most economical. Some 6 000 piles were driven on this work, and the final results showed a saving of 10 per cent.

The great success of the Simplex piles at the barracks attracted a great deal of attention throughout the East, and in a short time they were adopted for the foundations of a post-office at Lawrence, Mass.; a train shed at Chester, Pa.; and for the Produce Bank Exchange Building in New York City.

Then, after a competitive test, it was adopted in the foundations of the Pittsburg Terminal and Warehouse Company's warehouse in Pittsburg, Pa. This was one of the largest pieces of foundation work ever constructed in this country. Piles to the number of 4 800 were driven on this work — a total of 162 000 linear ft., or 31 miles, all of which were driven in three months' time. The lowest time bid received for heavy concrete footings was eighteen months. The rental saved by using the Simplex system was almost enough to pay the entire cost of the foundations.

From this time on the Simplex system was rapidly adopted in foundation work throughout the country. It has been used for the foundations of sheds, stacks, bridge piers, retaining walls, warehouses, foundries, traveling cranes, tall office buildings, residences, small office buildings, and, probably a unique field

for piles, under reservoirs. Here the piles are driven about 5-ft. centers under the floor of the reservoir and transmit the load of the water down to some firmer stratum of ground. In this manner the liability of the floor of the reservoir settling and cracking, with consequent leakage, is avoided and the piles are well worth the extra cost on this account.

Simplex piles, in nearly all kinds of ground, are driven to carry a load of 30 tons. To make sure of their ability to do this safely, many tests have been made on different work, some of them being of sufficient interest to mention here.

On the Pittsburg Terminal and Warehouse Company's work a cluster of four piles was selected at random and tested to 175 tons, showing no appreciable settlement, although the load remained on for a month and was close to the tracks of the Pittsburg and Lake Erie Railroad, being subjected to considerable vibration by the passing of heavy trains. On some work for the Westinghouse Machine Company, at Pittsburg, a cluster of five piles was tested to 300 tons, showing no settlement. In New York several piles were tested to over 45 tons with no settlement. In France recently a cluster of four piles was tested to a load of 245 tons without settlement. Throughout all these tests, and many more, the Simplex concrete pile has proved its ability to safely carry the loads designed for it, and we have yet to hear of the failure of any structure due to Simplex piles.

The question of the proper loading of Simplex piles is a matter of judgment and experience, depending largely on the character of the ground through which they are to be driven. In some cases they are carrying safely a load of 45 tons, and in others they are carrying as low as 15 tons. In all cases, however, it is safe to say they will carry a greater load, under the same conditions, than wooden piles.

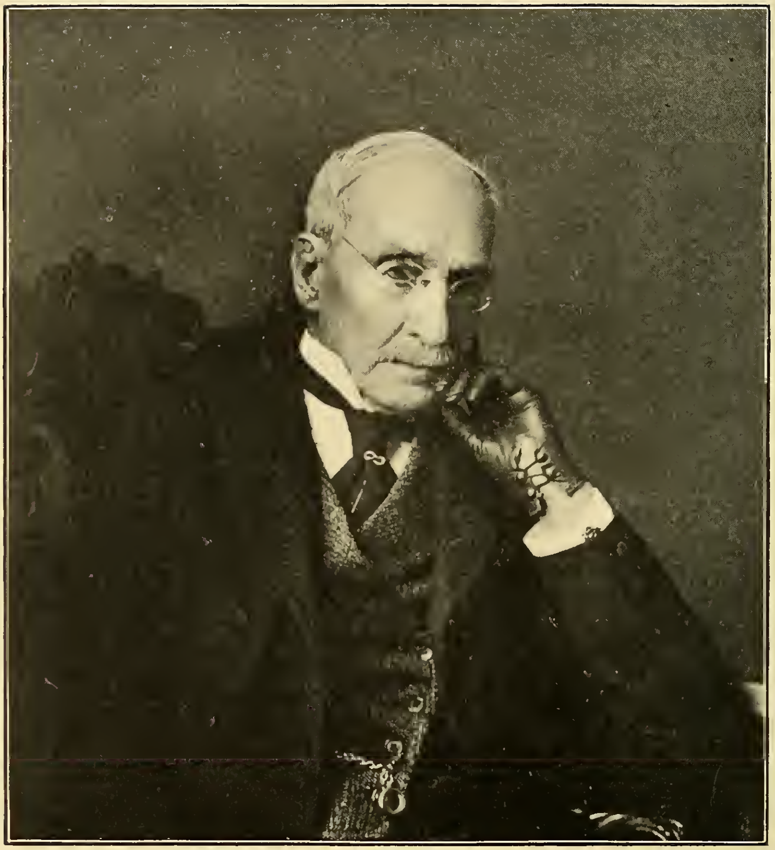
There are at present nine companies in this country, one in Mexico, and five in England and Europe operating under the Simplex patents.

The system is controlled by the Simplex Concrete Piling Company, Philadelphia, Pa., who have developed the system from its early days, and who have designed all the apparatus used in its work.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1907, for publication in a subsequent number of the JOURNAL.]

FIVE 16-INCH SIMPLEX CONCRETE PILES. CRANE FOUNDATIONS FOR THE WESTINGHOUSE MACHINE CO., PITTSBURG, PA., U. S. A.

Exposed, ready for putting on concrete cap. Note roughness of surface and cementation to the earth. These five piles were afterward tested with a load of 300 tons for ten days, under which there was no settlement.



Charles Haynes Haswell.

OBITUARY.

Charles Haynes Haswell.

Honorary Member Boston Society of Civil Engineers.

In the recent death of Mr. Haswell this Society has lost one of its Honorary Members and the profession has lost its dean.

Few deans have been distinguished by so long a life of activity and usefulness. Many have lived to be nearly ninety-eight years of age, but few have retained to the end both power of application and desire for work.

Charles Haynes Haswell was born in the city of New York on May 22, 1809. He died at his home, 324 West Seventy-Eighth Street in the same city, on May 12, 1907, from the effects of a fall in his dining-room which dislocated his shoulder.

The pain and shock proved too severe a strain for his great age, and the indomitable will and courageous spirit which had so often faced the dangers of life passed into the great unknown. Had Mr. Haswell been spared ten days more, he would have arrived at his ninety-eighth birthday. Two years more and he would have seen the full century mark on the journey; few can doubt, after considering his active physical and mental powers, that had his life been continued to this stage, the one hundred years would still have found him engaged in professional work. There was at the time of his death no more interesting figure in the whole realm of Engineering.

Mr. Haswell's death is a particularly significant event for this Society. He became a member on June 3, 1850, soon after the formation of the Society and before the organization of the American Society of Civil Engineers. He was therefore a member for more than fifty-seven years, and formed the link which connected the Society of to-day with that of 1848.

Let us now follow briefly the details of his active career.

Mr. Haswell's parents were of English origin, descendants from stanch Royalists, who, after the defeat of Charles II at Worcester, migrated to Barbados in the West Indies.

After an excellent education, of a somewhat classical flavor, young Haswell at the age of nineteen began his professional life by entering the well-known engine works of James P. Allaire;

here the rudiments of mechanics were soon mastered, and the alert mind of the apprentice turned to the more important work of design.

In 1829 Mr. Haswell married Miss Ann Elizabeth Bourne, of New York City, by whom he had three sons and three daughters.

In 1836 Haswell's attainments had become so conspicuous that the government invited him to enter its employ in connection with the enlargement of the navy, and for several succeeding years his energies were directed to the equipment of some of the most important vessels of war.

"Prior to 1839 the construction of all steam boilers was restricted to the ordinary merchantable plates of metal of uniform dimensions, but when the boilers of the United States frigates *Missouri* and *Mississippi* were designed, Mr. Haswell laid them down full size on the mold loft floor of the Navy Yard at Brooklyn, and defined the dimensions of each of the required plates to suit their location in the boilers, and in accordance with these dimensions they were rolled and trimmed. This was the first trial of such a proceeding and one that is now of universal practice." *

In 1850 Mr. Haswell's health became impaired. A board of surgeons declared him unfit for duty, but notwithstanding this fact he was ordered on service to the Mediterranean. It was found that the animosity of a clerk had prevented the finding of the board of surgeons from becoming public. Shortly after arriving in the East, it was plain that he was in no condition for work and he was returned home as "unfit for duty."

At other times, however, several voyages were made as chief engineer in charge of operation and maintenance of machinery of his own design. How much deeper and wider must have been the experiences of a mechanical engineer in those days, with the opportunity to witness at first hand the behavior, under actual trial, of machinery designed by himself.

An anecdote is related of young Haswell in connection with this period of his life which gives some idea of the strength and independence of his character. In fitting up the *Missouri* it was proposed to furnish her with horizontal smokestacks. Against this plan Mr. Haswell protested with so much zeal that he was suspended from duty for insubordination. It was afterwards shown by actual experience that the young engineer was correct and he was promised reinstatement if he would apologize to his superior officer, but this he refused to do, saying that he

* *Cassiers Magazine*, p. 440, 1900.

might be obliged to submit to injustice from others, but he declined to be unjust to himself. His career in the navy, however, was not destined to end with this incident for we find him soon again under pay of the Navy Department, and superintending the construction of machinery for four revenue cutters.

In 1843 Mr. Haswell assumed the duties connected with the office of engineer-in-chief of the navy, and in 1845 received formal appointment to that position which he filled until 1851. In 1848 he was a member of a board appointed to design four steam frigates; among them was the *Powhatan* which afterwards formed a part of the fleet under Perry at the opening of the Japanese ports. In the design of this frigate Mr. Haswell was obliged to make all of the working drawings, owing to a scarcity of men sufficiently skilled to be of material aid as assistants. The machinery for the *Powhatan* included some novel ideas, such as the setting of the engines in massive wrought iron frames. This frigate was retired from commission in 1886, at which time she still retained many of the original features of the design of 1848.

The task of planning so much machinery, together with other responsibilities, was enough to tax the energies of the strongest constitution, but when to this were added petty annoyances, jealousies and criticisms from those who really should have been his supporters, Mr. Haswell found that the office of chief engineer of the navy was no longer attractive, and in 1851 he tendered his resignation and entered upon the private practice of his profession in New York. He was in the prime of life and soon had ample opportunity to show to the world the high standard of his physical and moral endowments. Several merchant steamers were built under his direction, and he was frequently called upon in various directions to fill important positions. For a period of forty-two years, 1851–1893, he was surveyor of steamships for the marine underwriters of New York, Boston and Philadelphia. In 1858 he was elected president of the board of councilmen of the city of New York; later he became consulting engineer for the board of improvements, and on several occasions he acted as engineer for the board of health.

In 1862–63 Mr. Haswell was marine engineer of the Burnside Expedition and commanded a small steamer. At the bombardment of Fort Barton on Roanoke Island he ran her under fire to the assistance of the gunboat *Ranger* which had stranded on a shoal.

Many years after these events Mr. Haswell directed the

extensive improvements on Ricker's Island, and as late as the winter of 1905–6, during bitterly cold weather, he visited the work to see that it was properly executed. At the time of his death he was consulting engineer to the Board of Apportionment of New York City, and went three times a week to his office to perform the duties.

While Mr. Haswell's title to fame is founded primarily upon his design of the first steam yacht, the *Sweetheart*, which he launched in the East River in 1837, sometimes referred to as the Eve of vessels of her class, it is to his "Engineer's and Mechanic's Pocket Book" that he owes that wide familiarity with his name which exists in the profession. For more than half a century nearly every engineering office has contained a copy of this familiar book. It was first published in 1843, and since that time it has passed through seventy-two editions and has in the meantime grown from 284 to 1 051 pages.

In addition to the Pocket Book, Mr. Haswell contributed liberally to the literature of the societies with which he was connected. His "Reminiscences of an Octogenarian of New York City" covers the period 1816–60, and was published in 1897.

The social side of Mr. Haswell's nature was well developed and led him to form a wide circle of acquaintances. He was a member of the American Society of Civil Engineers, the Engineers' Club of Philadelphia, the Institution of Civil Engineers of London, and of naval societies in Great Britain and the United States. While at a convention of the Institution of Naval Architects of Great Britain in 1897, he was declared to be the oldest practicing engineer in the world.

He was dean of the Union Club in New York and was also associated with many other clubs. He was a constant visitor at the Engineers' Club of New York to the very last, and on the occasion of his ninety-fifth birthday a notable dinner was given him by this club; sixty-five covers were laid in honor of the veteran and a massive loving cup was presented to him. In replying to a toast Mr. Haswell gave reminiscences of his long life, and among other stories told he said that during his early career in 1837 he had occasion to recommend the construction of a towboat, but this was turned down by his superior officer who gave as his reason that there were already two towboats in American waters and there was no room for a third.

The long and picturesque life we have thus scanned as in a kaleidoscope has in turn gone to its long rest with the "great majority." Many a sun may rise and set before the engineering

profession is blessed with another member whose life and activities will be spared to as great a span. At the time of his birth, James Madison, the fourth President of the United States, was in office. There have been twenty-one Presidents since, so that Mr. Haswell might have seen twenty-two out of the twenty-five Presidents. When his eyes first saw the light there were but seventeen stars upon the flag, — Louisiana had not been admitted to the Union, neither had Maine; to-day the constellation numbers forty-five. Mr. Haswell was two years of age when the first steam printing press was invented; he was three when the intrepid Hull with the old frigate *Constitution* captured the *Guerrière*. He was five when the first vessel of war propelled by steam was launched at New York, and in that year Stephenson was already struggling to perfect the first locomotive. He had just passed his sixth birthday when Napoleon's long line of victories was broken at the battle of Waterloo and other military heroes blazed upon the horizon. Young Haswell was sixteen years of age when the Erie Canal was opened; he was twenty-eight when Victoria ascended the throne and eighty-eight when her diamond jubilee was celebrated, and at the advanced age of ninety-seven was still taking a deep interest in the procession of events precipitated by the active work of the different nations of the earth. A vast array of distinguished lives in all branches of human effort passed across the long perspective of his vision.

May the gallant struggle of Charles Haynes Haswell for the advance of the race, his long and well-tried faith in the achievements of man, and his undying loyalty to the best traditions of his profession prove an inspiration to guide our own lives toward the final goal.

Signed, DESMOND FITZGERALD.
CLEMENS HERSCHEL.
IRA N. HOLLIS.

Frank Walton Upham.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

FRANK W. UPHAM was born in Wayland, Mass., November 4, 1870, becoming a member of this Society April 17, 1901. Both of his parents were of old New England stock, prominent among his mother's ancestors being Samuel Whittemore, who lived in what is now Arlington, and who on the day of the battle of Lex-

ington, regardless of his eighty years, killed three British soldiers, was himself badly wounded but recovered to live until ninety-six years of age.

Mr. Upham received a high-school training in the town of Weston and immediately after graduating went to work for the late Mr. Frank P. Johnson, who at that time conducted a private engineering business in Waltham. After a two years' apprenticeship with Mr. Johnson, from whom he received most excellent recommendations, he entered the city engineer's office of Newton under Mr. Albert F. Noyes, and with the exception of a year spent with the Massachusetts Highway Commission, he remained there until it became necessary for him to seek a milder climate for his health. As an engineer, he was studious and painstaking. His notes and records remain a model of neatness and clearness. His kindly disposition won him many friends among his associates, with whom his memory will long linger.

In August, 1906, he married Miss Elizabeth F. Paddock, principal of the Franklin School in Newton. His home life was a very happy one and he became very much interested in church work, joining the Episcopal Church, of Auburndale, where he took an active part.

In his failing health very few, if any, of his friends realized his condition. With courage and cheerfulness he made his last fight, and it was with surprise and great regret that his friends learned of its being necessary for him to go to California to regain, if possible, his health.

After a stay of nearly a year in California, realizing he had not long to live, he greatly desired to see his home once more, so returned to Holliston, Mass., the present home of his parents, where after three weeks he passed away on the 3d of May, 1907.

While Mr. Upham's life, like that of many an engineer, was a quiet one, not distinguished by deeds proclaimed, yet to those who knew him intimately he stood out from among us by his quiet, genial manner and keen sense of humor, and he was one with whom it was always a pleasure to associate.

IRVING T. FARNHAM,
ROWLAND H. BARNES,
Committee.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

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THE CAUSE, TREATMENT AND PREVENTION OF THE "BENDS" AS OBSERVED IN CAISSON DISEASE.

BY PROF. J. J. R. MACLEOD, WESTERN RESERVE MEDICAL COLLEGE.

[Read before the Civil Engineers' Club of Cleveland, May 14, 1907.]

IN the employment of caissons in tunneling under rivers, and in the use of the diving suit in submarine engineering, it is well known, both to physicians and engineers, that certain peculiar symptoms are apt to attack the worker. The symptoms, popularly known as "caisson disease," or the "bends," or "the pressure," or "diver's palsy" may be of a very mild and transient character, or they may be of sudden onset and great severity, either leading within a short time to death or persisting with varying intensity until ultimately they leave the patient in a crippled condition.

Until comparatively recently there has been no systematic and competent investigation attempted of the cause of the disease. Affecting, as it does, only workers in compressed air, and not being, therefore, observed frequently by medical men, it received little attention until the year 1854, when Pol and Watelle,* two French physicians in charge of 64 men employed in a caisson on the banks of the Loire, published an account of the symptoms.

It would, of course, be out of place for me to give any detailed account of the symptoms here. Indeed, to do so would not only exhaust all your patience, but would occupy all my time, for the symptoms are of a very protean type; they may

* *Cit.* after Paul Bert, "La Pression Barométrique," p. 380.

be practically anything.* Perhaps, however, it may be well to briefly point out the main symptoms in a typically mild and in a typically severe case. And first of all let me point out that the symptoms never appear when the workman is in the compressed air; it is only after he has been decompressed that anything unusual is noticed. It is true that when he enters the compressed air he may feel somewhat uncomfortable; he may feel a stuffiness in the ears, or giddiness, or a peculiar feeling of resistance to movement, etc. All these sensations soon disappear, however, except when the man is suffering from a cold in the head, in which case the uncomfortable sensations in the ears may persist for some time. The cause of this stuffiness in the ears is that the air pressure on the inside of the drum of the ear, *i.e.*, in the tympanic cavity, is not immediately adjusted to what it is outside, thus causing the drum membrane to bulge inwards and become thereby stretched. By holding the nose and blowing, the sensation is immediately relieved, for by this act the pressure in the tympanic cavity is made equal to that without, through the Eustachian tube, which runs to the cavity from the back of the nasal passages. A cold in the head causes congestion of the lining of the Eustachian tube and thus blocks it, making the adjustment of pressure on the inside of the ear a slower process.

After being for some time in the compressed air there is usually noticed a frequent desire to pass water and sometimes a great drowsiness and several other minor sensations.†

During decompression (especially if rapid) there is usually a sensation of cold (due to the expansion of the air) and some breathlessness, but it is after his exit from the lock that the first real symptoms attack the caissonier. In the severest cases the man suddenly falls unconscious to the ground, his respirations become embarrassed, his heartbeat fluttering, and he may die in a few minutes. In other cases, consciousness is not lost, but the

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* To those whom it may interest, a full account of the symptoms will be found in the following papers:

1. Paul Bert: "La Pression Barométrique," Paris, 1878.
2. E. H. Snell: "Compressed Air Illness," London, 1896.
3. Heller, Mager, and Von Schrötter: "Luftdruck Erkrankungen," Wien, 1900.
4. Hill and Macleod: "Caisson Illness and Diver's Palsy," *Journal of Hygiene*, Vol. III, p. 407, 1903.

† In subjecting themselves to an air pressure of + 7 atmospheres in an experimental chamber, Hill and Greenwood, after learning how to blow up the ears, felt no discomfort. (See below.)

man suffers from fearful pains, especially in his muscles and joints, distressing breathlessness, paralysis, hemorrhages, cyanosis (blueness), deafness, etc. With proper care he may recover, but his recovery will be tardy, there remaining many " dregs " of the disease: paralysis, incontinence of urine, blindness, deafness, etc.

It should be pointed out here that the severe symptoms are now very rarely seen in caisson workers, although they are quite common amongst deep-sea divers, as, for example, in the sponge and pearl fisheries of Greece and Australia. They are noticed in careless diving where the divers, to get quickly to the boat, screw up the outlet valves in their helmets and in this way fill their suits with air, which carries them suddenly to the surface, where they decompress themselves by opening the valve. Among the Greek divers, Siebe and Gorman, the diving engineers of London, tell us that over a score of men lose their lives every year.

In the less severe cases the symptoms are often long delayed in their appearance. The worker may have returned home feeling perfectly well and may remain so for several hours. Pains in the joints and muscles and ears, giddiness, embarrassed breathing, vomiting, etc., may then occur, being not uncommonly first noticed after the patient has got warm in bed. Of greater or less severity, these symptoms usually disappear after some time, but not in all cases, for here, as in the acute cases, paralysis, deafness, etc., may remain as more or less permanent conditions.

Such is, briefly, a survey of the symptoms of this so-called disease. Having acquainted himself with the exact conditions and symptoms of a disease, the physician next calls in the aid of the scientific investigator to enable him to discover the cause. He knows full well that, having discovered this, it will be an easy matter for him not only to treat the disease, but, more important still, — for prevention is better than cure,— to prevent its recurrence. It is to experimenters such as Pasteur, Koch, Lord Lister, etc., that the medical profession, and consequently humanity at large, owes so much in the prevention of various diseases. Although the discovery of the cause of caisson disease is, when compared with that of anthrax, or sepsis, or tuberculosis, a very simple matter indeed, yet its very simplicity makes it an unusually interesting and profitable study, not only for the medical man, but for every one interested in the progress of scientific knowledge. To engineers it has a further interest in

the practical utility to which they are in a position to place the knowledge.

In investigating the cause of a disease we must first of all examine what structural damage it brings about in the animal body. And so with caisson disease, we find on *post mortem* examination that the chief lesions lie in the viscera and central nervous system (brain and spinal cord). In these locations are found congestion, with occasional hemorrhage, lacerations of the delicate nervous substance of the spinal cord. Sometimes, bubbles of gas are seen in the blood vessels or subcutaneous tissues.

These findings after death led the first investigators of this disease to conclude that its cause lay in the direct effect of the compressed air driving the blood out of the superficial parts of the body into the more deeply situated viscera. To quote A. H. Smith,* one of the chief exponents of this view, " Under high atmospheric pressure the centers will be congested at the expense of the periphery, . . . and . . . firm and compact structures (referring to the brain and spinal cord) will be congested at the expense of those more compressible."

Such a view, however, could not for long hold sway. Not only is it absurd from a physical point of view, but it is inconsistent with the fact that caisson sickness is never manifested while the workman is under the increased pressure. Its exponents were evidently unaware of an experiment conducted as early as 1835 by Poisseuille, who observed the circulation in frogs and young mice placed in a glass chamber and submitted to a pressure of from 2 to 8 atmospheres without the slightest effect. Their conception of the physical nature of the animal body, moreover, was entirely erroneous. They forgot that, physically considered, this consists of an elastic bag filled with fluid,— even the bones are, during life, composed to a considerable extent of water, — the solid parts of the body merely forming a sort of elastic meshwork. When we consider this, then, we see at once that in obedience to well-known laws of hydrostatics the pressure applied to the outside of the body will be instantly transmitted to an equal extent everywhere inside it. The only structure which will show a compression is an air-filled closed cavity, such as the intestines or the tympanic cavity of the ear. In the case of the latter cavity, as already explained, the pressure is adjusted by opening the Eustachian tube. It is inter-

* Dr. Andrew Smith: " Effects of Compressed Air," Detroit, 1886.

esting to note that the compression of the intestinal gases causes the caissonier to tighten his belt.

It was Paul Bert * who, in 1881, first clearly exposed the physical error in the congestion theories, and it is to this celebrated pupil of Claude Bernard that we owe the true explanation of the cause of the symptoms. The investigation first of all taken up by the pathological worker was now handed on to the experimental physiologist, and the remarkable experiments of Paul Bert and his successors leave not the vestige of a doubt as to the true cause of this disease.

Before describing these experiments let me briefly explain the causation. When an animal is introduced into compressed air, the tissue fluids dissolve the air in obedience to Dalton's law of solution of gases in fluids, which states that the amount of gas dissolved in a fluid is proportional to the pressure of the gas surrounding the fluid. Thus, if a fluid dissolve one volume of gas at one atmosphere, it will dissolve two volumes at two atmospheres, and so on. This dissolved air in the blood is quite harmless and the animal in no way suffers. Whenever the pressure of the surrounding air is suddenly lowered, however, as in decompressing quickly, then the dissolved air is thrown out of solution, forming bubbles which stick in the minute blood vessels and block them. In this way the blood cannot flow through its vessels, and the heart, still pumping for some time, causes the obstructed vessels to become engorged and sometimes to burst. Likewise in the other fluids of the body: in the tissue juices air bubbles are liberated and according to their location damage is done to various organs. If, for example, these bubbles form in the vessels or joints or nerves, they will cause the pains above described; if in the spinal cord, paralysis; if in the heart, heart failure; if in the lungs, breathlessness; if in the eyes, blindness, and so on. When decompression is slowly effected then no bubbles appear and consequently no symptoms. The whole mechanism may be well illustrated by a bottle of effervescing water, such as soda water. Such water contains gas in solution under pressure. When the cork is withdrawn, the pressure being suddenly relieved, bubbles of gas appear in the fluid; it effervesces. If, however, a pin hole be made through the cork and the gas be thus allowed to slowly escape, then in the course of time all the dissolved gas will leave the fluid without any bubbles appearing.

From this explanation it is evident that the proper treat-

* *Loc. cit.*

ment of a case of caisson disease is reapplication of the pressure followed by very slow decompression. Medical locks are commonly provided at caisson works for this purpose. By thus reapplying the pressure the bubbles become redissolved. To take the case of the bottle of effervescing water, if, while it is effervescing, the bottle be again corked, the effervescence will at once cease and the water become quiet.

The immediate cause of the symptoms is thus easily explained, but for practical purposes, from the engineer's standpoint, the explanation leaves us uninformed of many fundamental facts. It does not explain why some men should be prone to the condition and others not; it does not explain why long shifts should be a predisposing factor, and so forth. To throw light on these questions, and to fully prove the theory itself, a large series of experiments on animals has been conducted, first of all by Paul Bert, and subsequently by Lorrain Smith, Von Schrötter and Leonard Hill and myself.* I shall now proceed to give you a brief account of the chief of these experiments, and then in conclusion I shall state what laws for prophylaxis can be deduced, both from experiment, and from observation made on the disease itself.

In describing the experiments it will simplify matters to classify them according to the problems they were designed to solve, and the problems which we will consider in this connection are as follows:

Evidence that while in the compressed air there is no change in the circulation or in the other physiological processes of the body.

Evidence that the tissue fluids, when the animal is under pressure, dissolve gas in obedience to Dalton's law.

Evidence that on quick decompression symptoms exactly like those of caisson disease are produced, and that these are due to frothing in the blood and other tissue fluids. On the other hand, slow decompression is never followed by the symptoms.

Evidence that by reapplication of the pressure and subsequent slow decompression the symptoms disappear.

While in compressed air there is no physical change in the circulation or in the other physiological processes of the body. The following experiments by Leonard Hill, F. R. S., and myself prove the truth of this statement.

A frog was placed in a small cylinder closed at the ends by

* For references see p. 1.

removable windows of thick glass and connected with a cylinder of compressed gas (oxygen). A foot of the frog was tied out on a wire frame so as to stretch the web. The expanded web was adjusted so as to lie against one of the windows. A strong arc light was thrown through the chamber, and by applying a microscope to the outside of the window against which the web was stretched we could easily see the blood circulating in the blood vessels. Having studied this for the normal frog, we then quickly raised the pressure in the chamber by turning on the cylinder of compressed gas. Absolutely no change was produced in the circulation of the blood.

Messrs. Siebe and Gorman, the diving engineers of London, constructed for us a pressure chamber large enough for observation on dogs, cats, etc. This chamber was provided with an observation window and illuminated in its interior by electric light. In one case we placed in the chamber an anesthetized rabbit with its carotid artery connected with a manometer and on raising the air pressure in the chamber we saw not the slightest change in the blood pressure.

There can exist no doubt, then, that the old theory of a compressing of blood into the interior of the body from its superficies is wrong.

Regarding the other physiological processes, the fact that we have never seen an animal suffer any symptoms while under the pressure is itself sufficient evidence that there can be little change in those. For example, we have observed a monkey (Rhesus) that was placed in the chamber at a pressure of +7 atmospheres for 4 hr. three or four times a week for a month, and who was as well at the end of his experience as at the beginning. Towards the end of the 4-hr. shift he would often become sleepy. We have besides this observed mice, rats, cats, dogs, rabbits, and birds under pressures running up to 7 atmospheres and never noticed any symptoms.

All these observations on animals may possibly not seem sufficient evidence to prove that *man* shall not suffer when under pressure. Apart from the account given by workmen in caissons, there are, however, experimental observations by L. Hill and M. Greenwood, Jr.,* bearing on this question. These workers had placed at their disposal, by Messrs. Siebe and Gorman, a steel cylinder of 42.2 cu. ft. capacity, fitted up with mattress, blanket,

* L. Hill and M. Greenwood: "Influence of Increased Barometric Pressure on Man." Proceedings of the Royal Society, Series B, Vol. LXXVII, p. 442 (1906).

and pillows, so that a man could adopt a comfortable attitude inside of it. It was also furnished with electric light, telephone, gages, etc., and was connected with a diver's pump. Hill and Greenwood have frequently subjected themselves to increased pressure in this chamber, sometimes, indeed, up to +7 atmospheres, equaling a depth of over 210 ft. of water. Their first experiences under pressure were somewhat distressing on account of the discomfort in the ears, nervousness lest the chamber should burst, and inability to use the lips and tongue in speaking; but after a little practice neither observer found that the compressed air produced any effect on him. He felt perfectly comfortable and active. These experiments have now been repeated many times.

Observations have also been made with the intent of finding out whether the increased pressure causes any change in the chemical processes of the animal body. There are two general methods by which the physiologist determines the nature of the chemical changes in the animal; one is by an analysis of the urine (with consideration of the nature of the diet) and the other is by analyzing the expired air. Paul Bert recorded several observations bearing on this phase of the question, and more recently Leonard Hill and I have considerably extended his observations.

To study the chemical composition of the urine the observations were conducted on three dogs, the animals being compressed to +6 to +7 atmospheres for several hours a day and the urine meanwhile carefully collected and analyzed. Such investigations extended over a week or two. In none of the three dogs was any definite change in the urine noted. This conclusion is contrary to that of Paul Bert, but we have shown elsewhere that his analyses were not of sufficient accuracy.*

Regarding the analysis of the expired air, or, in physiological language, the respiratory exchange, Hill and I have conducted a long series of observations on mice,† rats, and rabbits, and more recently Hill and Greenwood ‡ have extended the observations to man.

In the investigations on lower animals we placed the animal in a steel chamber connected by tubing with a cylinder of compressed air at one end and at the other with a series of weighed

* Hill and Macleod: *Journal of Hygiene*, Vol. III, p. 407, 1903.

† Hill and Macleod: *The Journal of Physiology*, Vol. LXXIX, p. 492, 1903.

‡ Hill and Greenwood: *Loc. cit.*, p. 450.

U-tubes, those next the chamber containing pumice stone saturated with concentrated sulphuric acid and the next one soda lime. A constant current of air was kept passing through the chamber and tubes, which carried with it the exhalations of the animal. After the experiment the U-tubes were again weighed, the increase in weight of the sulphuric acid tubes indicating the amount of water given out by the animal, and the increase in weight of the soda lime tubes the amount of carbonic acid. After studying in this way the discharge of water and CO_2 from animals under normal pressure, we increased the pressure by regulating the inflow and outflow of air to the chamber by valves, always seeing that a current continued to pass through the tubes. The results were briefly as follows: At a pressure of +4 atmospheres and upwards, compressed air markedly diminishes the CO_2 output in mice, very greatly lessens the H_2O output, and increases the loss of body heat. This effect on body heat we determined by taking the temperature of the animal before and after being in the chamber.

In a long series of observations we found that different animals show a variable resistance to the compressed air, but the general nature of the result was always the same.

Our next problem was to find out what exactly it is in the compressed air which brings about the result. It might be due to several causes, among which two are of greatest importance, *viz.*, the poisonous effect of the increased amount of oxygen in the compressed air, and the cooling effect of the compressed air. We have investigated each of these factors. Regarding the former, it had already been pointed out by Paul Bert that prolonged exposure to even one atmosphere of pure oxygen slightly lowers the CO_2 output and temperature of mice, both returning to the normal on replacing the oxygen with air. Hill and I have confirmed this.* Now it is evident since air contains one fifth volume of oxygen, that at 5 atmospheres of air (that is to say, +4 atmospheres [+60 lb.]), the air in the chamber will contain one volume of this gas. This biochemical evidence of the toxic effect of oxygen is further confirmed when animals are subjected to higher pressures by very serious effects on the lungs and central nervous system. The effect of compressed oxygen on the lungs was first noticed by Lorrain Smith.† He found that at 170 to 180 per cent. (corresponding to +7 atmospheres air or a

* Hill and Macleod: Proceedings of the Royal Society, Vol. LXX, p. 455.

† Smith, Lorrain: *Journal of Physiology*, Vol. XXII, p. 315 (1898).

depth of 250 ft. of water) the lungs lose the power to actively absorb oxygen, and that after being exposed to such pressures for long periods of time the mice died of pneumonia. Thus, at 180 per cent. atmosphere, O_2, death occurred in 24 hr., and at 300 per cent. atmosphere, in 5 hr. We have repeated these observations of Lorrain Smith with, in general, similar results.

At still higher pressures of oxygen the nervous system becomes involved, producing most violent convulsions, usually resulting in death.

These results would at first sight seem to show that the effect of the compressed air in lowering the CO_2 and H_2O output from the lungs, and the body temperature, is entirely due to its high tension of oxygen, but a more critical examination has convinced us that such is not the case. From the above results we see that whereas at +4 atmospheres air pressure the depression is usually quite marked, it is only very slight in 1 atmosphere oxygen. Furthermore, and this is the important point, as the air pressure is increased above +4 atmospheres the diminution in the excretion of CO_2 and H_2O from the lungs, as well as the fall in body temperature, becomes very marked, much more so than in corresponding pressures of pure oxygen. Thus in +10 atmospheres air the depression is extreme, in +2 atmospheres pure O_2, only moderate. Nevertheless at continued high air pressure the poisonous effect of oxygen manifests itself on the lungs. When the air pressure is raised to +7 atmospheres it takes at least 24 hr. to produce any symptoms of lung affection. For shifts of 4 hr. duration a pressure of even +7 atmospheres (210 ft.) had no effect on the lungs of a monkey who underwent this experience several times a week for a month.

The depressing effect of the compressed air on small animals we have definitely shown to be due to the enormous cooling effect of the compressed air. Under pressure the air becomes saturated with moisture and so wets the fur of the animal and causes exaggerated heat loss. It is obvious that on man such increased heat loss will be of little moment. The greater bulk of his body in relation to his surface area, and the more highly developed power he possesses of regulating his balance of heat production and heat loss, when compared with such an animal as a mouse, will make the cool air have little effect on him.

It should be particularly emphasized here, however, that a partial pressure of oxygen exceeding 2 atmospheres is unsafe. At this pressure both the pulmonic and the nervous symptoms may supervene. Two atmospheres oxygen corresponds to a

pressure of 10 (+9) atmospheres air, or a depth of about 300 ft. Allowing a liberal factor of safety and considering that below the above pressure no untoward results have ever been noted we may state that diving to 210 ft. is permissible. Indeed, our experiments show that with short shifts there cannot probably be any risk in diving to 7 atmospheres, 250 ft.

When the animal is under pressure, the blood and tissue fluids dissolve gas in obedience to Dalton's law.

To study this point, Hill and I placed an anesthetized dog in the large pressure chamber above described and connected the carotid artery by india-rubber tubing with an outlet tube in the chamber. When the valve on this outlet tube was opened, a sample of blood was readily collected, the pressure squeezing it out of the animal. We then estimated the amount of gas dissolved in the blood by means of the apparatus devised for this purpose by Leonard Hill. Our results are given in the following table and will be found more fully reported elsewhere.*

Atmosphere.	Duration of Exposure.	Am't of Gas in 100 gr. of Blood. O_2	CO_2	N	Calculated Amount of N_2 which 100 gr. Blood should Contain if Dalton's Law is Obeyed.
$6\frac{2}{3}$....	30 min.	22.10	37.28	8.41	9.42
	2 hr., 45 min.	25.81	40.66	11.61	9.42
$6\frac{2}{3}$....	1 hr.	14.3	45.7	10.14	9.42
	1 hr., 30 min.	10.56	39.41	12.9	9.42
$5\frac{1}{3}$....	45 min.	14.74	37.7	7.48	7.78
	1 hr.	16.55	39.24	9.27	7.78

Considering in this connection the nitrogen alone, and remembering that in the analysis of the blood an excess of oxygen is a common error, we see that Dalton's law is obeyed. It will further be noted from the table that it does not take very long for the blood to dissolve the requisite amount of gas.

Hill and Greenwood † have more recently investigated this question on themselves, not indeed by analyzing their arterial blood gases, for that would be an impossible experiment on man, but by determining the amount of gas dissolved in the urine. In order to increase the formation of urine they drank large quantities of warm water and then placed themselves in the chamber

* Hill and Macleod: *Journal of Physiology*, Vol. XXIX, p. 382 (1903).

† Hill and Greenwood: Proceedings of the Royal Society, Series B, Vol. LXXIX, p. 21 (1907).

above described, the pressure being raised to a definite amount. When this had been attained, the bladder was emptied and the urine collected in a vessel which was then closed airtight. Another sample of urine was collected 10 min. later, slow decompression was then started, samples of urine being collected every 10 min. during it, and for some time after the pressure had returned to zero. The resulting samples of urine were then analyzed for dissolved gases in the usual manner. Under normal conditions of atmospheric pressure and temperature it was found that 100 cu. cm. urine dissolved 1.4 cu. cm. nitrogen from the air. Under pressure the following table gives the average of the various experiments:

Pressure.	Average Amount of N_2 Found, Per Cent.	N_2 Per Cent. Calculated, Supposing Urine Followed the Pressure.
0 lb.	1.14	1.1
30 lb. for less than 10 min.	1.99	3.3
30 lb. for more than 10 min.	3.32	3.3
45 lb. for less than 10 min.	4.29	4.4
45 lb. for more than 10 min.	4.23	4.4
30 lb. during decompression	3.63	3.3
15 lb. during decompression	2.75	2.2
0 lb. on decompression	1.99	1.1
0 lb. after decompression	1.64	1.1
0 lb. more than 15 min. after decompression	1.13	1.1

Regarding solution of the gas, it is seen that in 10 min. this was attained. This is a surprisingly short time, and in considering the results of the observation it must be remembered that the kidney is a very vascular organ, *i.e.*, richly supplied with blood, and that consequently its tissue fluids, including the urine which it excretes, will come to dissolve the same amount of gas as is in solution in the blood much more quickly than would be the case in less vascular organs or tissues, such as fat, etc. This point is of importance with regard to the question of how long the shifts in compressed air ought to be. In this connection it is of interest to note that Vernon* has found that the fat of mammals dissolves at least five times as much nitrogen as an equal volume of water or blood plasma. This gas-dissolving power of fat explains why gas bubbles are so often formed in the spinal cord and other structures rich in fat when decompression is too rapid.

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* Vernon: Proceedings of the Royal Society, Series B, Vol. LXXIX, p. 366.

Evidence that on quick decompression symptoms exactly like those of caisson disease are produced, and that these are due to frothing of the blood and other tissue fluids.

The experiments to prove this fundamental point consisted in placing animals in compressed air for a certain time, and then decompressing rapidly and examining the behavior of the animals. Paul Bert was the first to perform such experiments, all of which, along with many others, have been repeated by Hill and myself.

The following brief outline of the chief of these may be of interest:

1. Two toads were compressed for 1 hour to 20 atmospheres O_2 and rapidly decompressed. The animals went into tetanic spasms and swelled to double their natural size with the gas set free in the tissues. The heart was enormously distended, tense and scarlet in color. On letting out the froth (by puncturing it) the heart began to beat vigorously. (L. Hill.)

2. Rat in 20 atmospheres O_2 for 6 min. Rapid decompression. Respiration almost failed, *tetanic spasms*, paralysis of hind legs, contracted pupils; died in 80 min. Air bubbles were found in the liver, mesenteric vessels, numberless small ones in the mesenteric fat, in the uterus and fœtal membranes (the rat was pregnant). The spleen and intestines were greatly congested. There was almost no blood in the heart. (L. Hill.)

3. A large cat, two half-grown rabbits, two large rats and two white mice were placed in the chamber constructed for us by Messrs. Siebe and Gorman and the air pressure was raised to 105 lb. (+7 atmospheres). A ventilation current was maintained. All the animals appeared, by observing them through the window, to be perfectly normal. At the end of an hour rapid decompression was brought about. The chamber filled with mist owing to the cooling of the expanded air. When the mist cleared we saw that the cat and one rabbit were dead, while the other rabbit was in violent tetanic convulsions. On opening the chamber the rats were found to be dead. The second rabbit died also and the mice alone survived. Emphysema (air bubbles) of all the tissues, and frothing of the blood in the right heart and lungs, were found on examining the animals *post mortem*. In one of the rabbits (an albino) hemorrhage could be seen in the blood vessels of the retina (nervous layer of the eye).

These three experiments, selected from a long series of similar ones, and absolutely typical, prove sufficiently that very rapid decompression means certain death, and that the symp-

toms are exactly those of caisson disease. It might be argued, however, that the length of time taken in decompressing in the experiments is far shorter than that adopted even in the most careless caisson work or in deep-sea diving. I shall, therefore, give examples of experiments where similar symptoms supervened after a decompression which occupied a longer time than that ever taken in decompressing caisson workers.

A Rhesus monkey, a rat and two mice were compressed to +7 atmospheres for 4 hours. The animals seemed untroubled by the pressure. Decompression was started at 4.30 P.M. by opening a small tap in the chamber; the last part of the decompression was hastened, and when, at 5.25, the pressure registered 10 lb. to the square inch, a large valve was opened and the pressure quickly brought to zero. On opening the chamber the monkey and other animals seemed perfectly normal. On removing the monkey from the chamber he struggled to escape, but in the course of a minute or two suddenly became quiet and lay on his side gasping and giving a peculiar cry. He gradually got more and more dyspnoeic (breathless), and his lips, tongue and face markedly cyanotic (blue). Despite careful treatment and artificial respiration, he died in 10 min. after removal from the chamber. On *post mortem* examination it was found that the blood in the heart was frothy and that bubbles of air were present in the mesenteric veins. The decompression, though slow enough to obviate symptoms in the smaller animals, was evidently too rapid for the monkey. It occupied an hour, a period of time never given in caisson work for this purpose.

The tissues of certain of the animals used in the above experiment were examined under the microscope and showed exactly the same hemorrhages and air bubbles that have been observed by pathologists in men dead of caisson disease.

In a case in which another monkey was subjected to +7 atmospheres for 4 hours ($2\frac{1}{2}$ hours being taken to decompress) no symptoms were noted, and the experiment was repeated at least fifteen times. Similarly, in other animals slow decompression was never followed by any symptoms. These experiments, then, leave not a particle of doubt that the sole cause of caisson disease is the liberation of bubbles of gas in the tissue fluids.

This brings us to the discussion of perhaps the most important point of all, *viz.*, *how long ought to be taken in the process of decompression in man, and what means may he adopt to prevent the formation of air bubbles?* In the experiment of Hill and Greenwood on themselves, referred to above, a long time was

taken in decompressing; for example, after 54 min. in a pressure rising from 0 to +90 lb., 2 hr. 17 min. were taken in decompression; after +75 lb., 95 min.; after +75 lb., 120 min.; after +75 lb., 105 min. These observers never suffered from other than slight and occasional neuralgic pains (the "bends") and from these only in the first observations, for they soon learned that exercise and massage of the body during decompression entirely obviated the pains.

The object of muscular movement and massage is to assist the circulation of the blood. Its importance will be evident from the following observations: During slow decompression from +75 lb. pressure, Greenwood moved all the limb joints at frequent intervals with the exception of the knees. Subsequently pains and stiffness were detected in the knees and nowhere else. In other cases all the joints were moved, when no after effects of any kind were experienced. Greenwood is a thin man with little subcutaneous fat, so that massage in his case was not necessary. In the case of Hill, who is a large, stout man, on being compressed from +5 atmospheres in 155 minutes, he moved all his joints frequently and on emerging from the chamber felt no discomfort. In the evening, however, pains appeared over the chest, where there was a large amount of subcutaneous fat. These pains were followed by a skin rash and were evidently due to air bubbles. In the fat an excessive amount of gas is dissolved so that it is much more slowly thrown out of solution than in the blood or other tissue fluids. By massaging these parts the circulation of the blood is assisted and the dissolved gas, therefore, carried into the general circulation and got rid of. Hill and Greenwood recommend that all caisson workers while in the decompressing air lock should be instructed to perform muscular movements and practice massage of the parts which they cannot move.

From Hill and Greenwood's observations on the behavior of the gas dissolved in the urine after decompression we see that the last stage of decompression should be very slowly regulated.

When we contrast the experimental results with the periods of decompression employed at some of the chief caisson works we shall see that instead of its being surprising that caisson disease should occur even when moderate care is adopted, it is a wonder that cases are not much more frequent.

The following table from the article of Hill and myself in the *Journal of Hygiene* gives the average time employed in caisson operations.

Periods of Shift and Decompression at Caisson Works.

Atmosphere (maximal).	Length of Shift.	Period of Decompression.	Place.
$4\frac{1}{4}$	4 hr.	30 min.	Chalonnes
2	—	10 sec.	—
$3\frac{1}{2}$	4 hr.	12–15 min.	Vehl
		(Rule often broken by men.)	
$3\frac{1}{2}$	—	20 min.	—
3	8 hr.	4–5 min.	St. Louis
$3\frac{1}{2}$	4 hr.	10 min.	St. Louis
4	3 hr.	18 min.	St. Louis
2–3	8 hr.	4 min.	Blackwall
		(Often shortened to 30 sec. by men.)	

It will be seen at once that the decompression is, in all cases, dangerously short.

It is, of course, evident from our experimental results, as well as from the experience of caissoniers, that in determining how long a time ought to be taken in decompression, consideration should be taken of the length of shift. In low pressures up to above 3 atmospheres the shift may be quite long, for it is probable that within an hour, at least, as much gas will have become absorbed as is going to be. On the other hand, at higher pressures, we must endeavor to prevent the body from absorbing all the gas that it might absorb, and to do this we must shorten the shift.

From a consideration of our experimental results and from a study of the literature bearing on this subject, we would suggest the following times of compression and decompression as safe for different depths:

Atmosphere.	Lb. Pressure.	Shift.	Decompression Period.
+1 to +2	15 to 30	4 hr.	30 min. to 1 hr.
+3 to +4	45 to 60	4 hr.	$1\frac{1}{2}$ min. to 2 hr.
+5	75	1 hr.	$1\frac{1}{2}$ min. to 2 hr.
+6 to 7	90 to 105	30 min. to 1 hr.	2 hr.

It is impossible to give a general figure from which to calculate the proper time for decompression, since the length of shift must be taken into account. In general, however, it can be stated that for pressures up to 3 atmospheres the shift may be 4 hr. and the decompression at least 30 min. an atmosphere. Above 3 atmospheres the shift ought not to be so long and the decompression ought to occupy from 20 min. to 30 min. an atmosphere. Care should always be taken not to hurry the last stages of the decompression. To prevent men breaking the rules, the decompressing lock should be provided with one cock

only, which will allow decompression to take place in the given time. A separate lock should be provided for the rapid passage of material. The chamber should also be kept warm, as in decompressing the expansion of air greatly lowers the temperature.

Evidence that by reapplication of the pressure, followed by slow decompression, the symptoms disappear.

In the experiment in which we observed the circulation in the web of the frog subjected to a high pressure in the small chamber, we noted, as already stated, that the pressure alone produced no change. When, however, we suddenly decompressed by opening a tap in the chamber, a most remarkable change was seen in the circulation. Bubbles of gas, some small, others large, were seen to form in the blood, soon blocking the vessels and in this way entirely stopping the flow of blood. Having observed this we reapplied the pressure, with the result that the bubbles again went into solution in the blood, so that they disappeared, and the blood began to circulate in a perfectly normal fashion. We then slowly decompressed and removed the frog unscathed from the chamber.

In the treatment of caisson symptoms it is necessary in reapplying the pressure that no time be lost after the symptoms appear. The following instructive experiment performed by us in the large chamber above described will make this clear: A large hutch rabbit was kept under a pressure of + 7 atmospheres for 4 hours and then was quickly decompressed. In a minute or so, typical decompression convulsions appeared. A cylinder of compressed air was emptied into the chamber and the pressure thus reapplied. The symptoms, however, remained unabated, and the rabbit soon died. It was evident, from the experiment, that for the reapplication of pressure to be of any avail the pressure must be very quickly re-established and no time be given for the air bubbles to tear up and damage permanently the nervous tissues, or to produce stasis of the circulation for a long period. We, therefore, repeated the experiment with the modification that the pressure was more quickly reapplied.

A cat and a hutch rabbit were subjected to an air pressure of + 7 atmospheres for 4 hours. Decompression was effected to zero in about 5 sec., and as quickly as the taps could be opened (about 5 sec.) a large cylinder of compressed air was delivered into the chamber, thus raising the pressure to + 95 lb. in about 2 min. In this experiment we did not wait for the symptoms before

reapplying the pressure. At the moment of decompression the cat sprang to the window, excited, and soon became entirely paralyzed in the limbs, so that it fell helpless on its side, its head meanwhile showing continuous side-to-side pendulum-like movements. On recompressing, these symptoms gradually disappeared, the head movement being the first to go. The pressure was maintained for 45 min. and then was slowly lowered to zero. The cat and the rabbit (which had shown no symptoms) were found to be perfectly normal when they were removed. There is no doubt, then, that recompression, after rapid decompression, causes re-solution of the gas bubbles in the blood, etc., and can save the life of the animal.

Recompression has been tried at several caisson works, and when intelligently used has been found to yield excellent results. For its application a medical lock is constructed (Hudson tunnel, Blackwall tunnel). The treatment must be applied at once and must be controlled by a medical man. We cannot believe the statement by some engineers that this treatment is of no use. We can only surmise that the treatment has not been adequately adopted.

Such is, in brief, the summary of what seems to me the fundamental experimental work on this question. There are, however, one or two further questions about which, for the sake of completeness, it may be well to say a few words. These are especially with reference to the choice of men for high pressure work and the question of ventilation of the caisson.

The choice of men. Both in deep-sea diving and caisson work the men should be young and in every way healthy, of temperate habits, and with little subcutaneous fat. Pol and Watelle * state that young men of eighteen to twenty-six stand the work best; out of 25 men discharged on account of symptoms, 19 were over forty years old. E. H. Snell † found at the Blackwall tunnel that men below twenty years of age were, with reasonable care, immune to caisson disease. Above forty-five years of age, according to Snell, the work is extremely dangerous. Regarding habit of body, A. Smith compiled the following table from the records at Brooklyn Bridge of men under forty-five.

	Spare.	Medium.	Heavy.
Lost little or no time from sickness..........	25	14	3
Taken sick..............................	28	22	26
Paralyzed..............................	2	3	8
Died..................................	—	—	3

* *Loc. cit.* † *Loc. cit.*

Why a stout man should be more susceptible than a spare one is made perfectly clear from the experiments of Hill and Greenwood. Snell excluded old and heavy men from the Blackwall tunnel caissons and lost no cases. There is no clear proof that long continuance at the work renders a man immune. Old hands are as susceptible as new ones. No man should be employed who has not been medically examined as to the state of his heart and lungs and blood vessels. The men should be tested at low pressure first, and those who suffer from symptoms should be discharged.

Ventilation. It is well known that, in a confined atmosphere, man sooner or later suffers from the accumulation of poisonous gases. The criterion of this pollution of the atmosphere is the amount of carbonic acid (CO_2) found present. When the percentage of CO_2 in the air rises above 0.1 per cent., evil effects are common.* Now under pressure it is evident that such a gas will be still more dangerous. As a matter of fact, E. H. Snell reports that an "increase of CO_2 from 0.04 per cent. to 0.1 per cent. at 30-lb. pressure is the forerunner of much illness." He found that by free ventilation of the caisson, so as to remove this CO_2, the illness dropped from seven cases a day to one case in two days. His very striking results prompted Snell to suggest that caisson disease might actually be due to the setting free of CO_2 in the body during decompression. Such a conclusion is, however, undoubtedly wrong, as is proven by an analysis of the air set free in the tissues in caisson disease, which shows it composed mainly of nitrogen. That a percentage of 0.62 per cent. CO_2 in the compressed air (+31 lb.) does not produce any untoward results was proven by Hill and Greenwood in the experiment already described. Nevertheless, ventilation is a matter which should be carefully provided for, for otherwise the CO_2 and other poisonous constituents of polluted air will have their usual depressing effects on the workmen and render them more prone to suffer from decompression symptoms. The average rate of ventilation should be between 8 000 and 12 000 cu. ft. per man per hour.

The nature of the soil has also an influence in predisposing to caisson disease. It is seen distinctly by Hunter at the Forth Bridge caissons; when soft wet silt was being removed or when concreting was going on illnesses were very frequent. In working

* It should be clearly understood that these evil effects are not due to the carbonic acid itself, but to some other toxic property which the CO_2 content seems to run parallel with, and is, therefore, a measure for.

on the new water intake in Cleveland it was the impression of the medical man in charge that the air in the caissons sometimes became polluted with gases from the earth and that then sickness was common. That may undoubtedly be true, for such gases as sulphureted hydrogen will be more toxic under pressure. Decomposing organic matter should, of course, be removed and earth pails should be provided for the workmen.

As a result of the foregoing investigations and observations we may conclude that caisson work, even to a depth of over 200 ft., is undoubtedly quite safe, provided decompression be slow enough and the other conditions indicated in this article are adhered to. And deep-sea diving, in short shifts, to even greater depths, is unquestionably quite safe. The responsibility of those who allow short decompression periods in caisson works is clear; every death or case of paralysis from air embolism must be set down to the negligence of the contractor.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1908, for publication in a subsequent number of the JOURNAL.]

THE TUNNEL AND RIVER SHAFT OF THE DETROIT WATER WORKS.

By James Ritchie, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, June 11, 1907.]

During a part of the years 1904 and 1905 the writer had charge of the construction of the tunnel and river shaft of the Detroit water works, representing the contractors, The C. H. Fath & Son Construction Company of Cleveland. The work was designed and the construction superintended by Mr. C. W. Hubbell, chief engineer of the Detroit waterworks.

Before making a contract for this work the city of Detroit had built a tunnel from the pumping station to a point near the bank of the Detroit River, a distance of about 1 000 ft., and had constructed a gate chamber and a shore shaft with 50 ft. of river tunnel. This work was done with their own men by day labor and without the use of compressed air. The shore tunnel was 10 ft. inside diameter and was placed with its axis at a distance of 26 ft. below the surface of the ground. The shore shaft had an inside diameter of 10 ft. and a total depth below the surface of the ground of 78 ft., 6½ in. The axis of the river tunnel was at a distance of 69 ft. below the surface of the ground, or 63 ft. below the surface of the water in the Detroit River. The inside diameter of the river tunnel was 10 ft., and the tunnel was constructed of four rings of shale brick laid in Portland cement mortar. The diameter of the excavation was 13 ft. After completing the first 50 ft. of the river tunnel, the city put in a timber bulkhead and prepared to let a contract for the rest of the tunnel, the river shaft and the intake crib and crib house. The latter items, namely the crib and crib house, were constructed by the W. J. Gawne Company of Cleveland, and do not enter into this discussion.

The contract for the river tunnel and shaft covered 3 185 ft. of tunnel from the end of the 50 ft. built by the city to a point 75 ft. beyond the center of the intake crib, and a river shaft of 10 ft. inside diameter placed at the center of the crib. The end of the tunnel was finished by two bulkheads 25 ft. apart, to

permit of a second crib and shaft being constructed should it be determined to extend the tunnel.

The contracts were awarded April 8, 1904, and provided for the completion of the tunnel and river shaft within eighteen months, or on October 7, 1905, and for the completion of the crib ready for sinking the river shaft within ten months, or on February 7, 1905. Six months were then to be allowed the contractor to complete the crib and crib house after the contractor for the river shaft had completed his work on the crib.

Work was commenced on the ground at the shore shaft on May 1, 1904, and consisted of setting up the machinery, building engine and boiler house, cement shed and offices, installing the elevator supports and preparing for the work of construction while awaiting the arrival of the materials. The power plant consisted of two boilers, one Ingersoll and one Rand air compressor, each 18 by 24 in., one electric generator and engine for operating same, one elevator hoisting engine, two drainage pumps for removing water from the tunnel and one boiler feed pump. The only part of the plant not in duplicate was the electric lighting, and to provide for emergencies the city lighting plant was connected to our tunnel line by a special switch.

On June 14, 1904, we commenced laying brick, and continued without using compressed air until we had completed about 40 ft., when work was stopped in order to install the air locks. These were two in number, the working lock being 5.5 ft. in diameter and 22 ft. long, set on the bottom of the tunnel and enclosed in brickwork and cement, and the emergency lock above the working lock, to be used in case of accident. The emergency lock was at all times open to the tunnel, so that if the working lock were closed the men could escape any danger by entering the upper lock, closing the door and locking out towards the shore shaft. Underneath the working lock was a 6-in. iron pipe for blowing off the tunnel, provided with a valve on the atmosphere end, and above the lock was a pressure regulating pipe with a safety valve on the atmosphere end, by which the air in the tunnel could be ventilated by raising the pressure above that at which the safety valve was set. Compressed air was furnished to the face of the work through a 5-in. pipe, which was carried along as the work progressed, and the end of which was at all times within 50 ft. of the working face. Water was carried to the face through a 2-in. pipe and kept close enough to the work to supply the mortar boxes through 25 ft. of hose. Electric light wires and telephone wires at all times extended to the face and

maintained light and communication. The telephone gave us the most trouble, as the instruments could not stand the atmospheric conditions for any great time without repair, but they were well worth any trouble that they caused us.

After the air locks were in position and found to stand the pressure, work was continued excavating and bricking in without serious delay, and the only stops made were on Sundays and holidays. Each Sunday the tunnel was thoroughly cleaned and ventilated, wires overhauled, telephone adjusted and other necessary work on the plant performed, ready for the night shift to go on at 11 o'clock. There were two shifts of miners, one going on at 11 P.M. and the second at 7 A.M. The bricklayers went on at 3 P.M. and bricked up what had been excavated by the mining shifts. For about 1 000 ft. after the air locks were placed, the pressure was 8 to 10 lb.; for the second 1 000 ft. it ran from 10 to 20 lb., and for the rest of the tunnel from 20 to 27 lb. At one point where bad ground was encountered, the pressure for about 12 ft. of working distance was 37 lb. The tunnel was completed as far as the location of the river shaft, and the sump under same was then built, after which the remaining 75 ft. of tunnel and the two end bulkheads were constructed. This work was completed on the fourth day of April, 1905, and work was commenced on the river shaft at the crib. The entire time occupied in constructing the tunnel was 9½ months from the first laying of brick, or an average of about 335 ft. per month; but from June 14 to August 1, 1904, we only built 200 ft., being delayed by putting in the air locks and scarcity of brick, the latter coming very slowly at first. In the month of January, 1905, we built 454 ft., 4 in., during which we reached our maximum of one day's work, namely, 21 ft. 2 in., on January 23; 20 ft. 3 in., on January 16; and an even 20 ft. on January 9. Our average during the month of January was 17 ft. 6. in., per day.

The methods of carrying on the work are probably familiar to most of you, but to some they may be new. The mining shifts consisted of one foreman, four miners and six muckers in each shift, also two drivers and one lock tender.

The first mining shift excavated the top half of the tunnel to such distance from the end of the brickwork as the foreman considered could be bricked up in 8 hours, and then took out as much of the bottom as they could in the remainder of their shift. Before commencing their excavation they had to strike the centers and put in the floor and track through the section of tunnel completed by the last shift of bricklayers.

The second mining shift completed the bottom and trimmed the circle and set in place the form for the invert. The reason that it requires more time to do the second half is on account of the men having to lift a large part of the material from three to five feet to place in the cars.

The bricklaying shift consisted of four bricklayers, six to eight helpers, two drivers and one lock tender. The number of brick to the foot being about 825, it will be seen that our average for the month of January of 17.5 ft. meant the laying of about 14 440 brick in 8 hours, or 3 610 brick by each man. This means from 7 to 8 brick per man per minute, and when it is remembered that the keying up of the arch can only be done by one man, and that it ordinarily requires from 45 minutes to one hour to key up, it will be seen that in laying the bottom a much faster rate must be kept up. Besides this the centers have to be set requiring from 20 to 30 minutes, which again operates as a delay. The maximum day's work of 21 ft. 2 in. was laid up by the bricklayers in 9 hours, and required 17 464 brick, or an average per man of 4 366.

The men outside the air lock were divided into two shifts of twelve hours. The day shift consisted of one engineer, one elevator man, one driver, and from two to four laborers. The night shift consisted of one engineer, one fireman, one driver and two laborers. The arrangement was as above until we found it necessary to make three shifts on top, leaving only the engineer, fireman and elevator man on twelve-hour shifts.

Mules were used for hauling the excavated material out of the tunnel to the air lock, from which it was taken on the elevator to the surface and again hauled by mules out on the dump. The month in which we made the best record was full of snow and sleet storms which impeded us in handling the material on the dump, and also in delivering materials into the tunnel. The latter work was done in the same manner as the removing of the earth, namely, by means of mules. The cars used in hauling earth were so made that the sides and ends being removed they were suitable for hauling brick. Also there were boxes provided in which the cement and sand were mixed dry and thus sent into the tunnel on the cars, the mortar being wet and mixed in boxes at the face of the work. The mules changed shifts with the men, and went in and came out after a few trials as easily as any one. After one mule was killed by falling down the shaft, bars were put up to prevent such accidents, and the mules rode up and down like old miners. One mule only was obstinate as to going

into the tunnel, and when he was once induced to go in, the air seemed to intoxicate him, and he ran down the tunnel and drove the men to the furthest limits, winning in the first round. This, together with his power of striking a blow with his feet, caused him to be christened "Terry McGovern," and he was used on top in future to haul out on the dump. The lintels over the shaft-house doors showed many marks of his hoofs, and his drivers were kept busy dodging him.

The only accidents that occurred in connection with the tunnel were two in number, one being when a driver fell and had his leg broken under a car, and the other when a laborer on top had two fingers crushed under the side of a car. Several men were affected by the bends, but none very seriously. The company provided facilities for hot baths for the men at the power house, also for coffee without limit. Medical attendance and examination of the air were also provided for. Every man who worked in compressed air had to be examined before he was employed to see that he was in a suitable physical condition to work in the tunnel.

Preliminary work on the river shaft was commenced on March 16, 1905, by taking tools and materials out to the crib, erecting derricks and setting up engines and boilers. The shaft was designed to be built inside of a steel cylinder having a diameter of 14 ft. at the bottom, with a cutting edge extending 3 ft. below the curb which held the brickwork. This cylinder was to be sunk to the bottom of the river through an opening in the crib, and then to be sunk through about 26 ft. of earth to the top of the tunnel. Guide timbers were placed so as to keep this cylinder in a vertical position, the cylinder was then placed on a raft inside the crib and a watertight floor put in under the curb.

The raft was so constructed that it could be removed when the shaft had nearly reached the bottom of the crib by releasing the lines on one end and pulling the timbers out at the other. To prevent accidents, the lines holding the raft were attached to the heavy cross timbers of the crib at the top so as to support the shaft in case it leaked enough of water to overcome its buoyancy. Also a pulsometer was placed inside and hung from the derrick, steam for same being furnished through a pipe from the auxiliary boiler with hose connection. The steel shaft was made in sections and riveted together on the crib as the cylinder was sunk. The brickwork was started on the curb and was successfully built up for a height of about 16 ft., when the shaft was found

to be so close to the bottom that the raft had to be removed in order to permit the shaft to enter the opening left for it in the bottom of the crib. With misplaced confidence in the pulsometer and the night watchmen, the shaft was left over night; the pulsometer acted badly, the watchmen thought they knew how to correct it, did not blow the whistle for assistance as they should, and neglected to use the buckets to bail out the shaft, which would have saved it, and the shaft filled with water and sank about four ft. into the bottom of the river. It was in its proper location, however, and work was at once commenced to lower the water around it so that the steel cylinder could be extended by riveting on the top section. Several attempts to do this were unsuccessful, and finally the ports through which water entered the crib were blanketed and the inner chamber of the crib was pumped down low enough to permit the riveting to be done, after which it was easy to pump out the shaft. The watertight floor was then removed and the brickwork continued to the top of the lower cylinder. As the brickwork was built up, the shaft kept sinking into the clay, which was carefully excavated so as to keep the shaft plumb, and there was so little resistance by friction that without any external loading the shaft sank to the top of the tunnel, landing almost exactly in its proper location. The above described accident delayed the work about 30 days, namely, from April 28 to May 25. The shaft was completed, including the underpinning, on June 19.

Meanwhile, from April 5 to May 11 and from June 14 to July 1, men were at work scraping and washing the tunnel, finishing by cleaning the shaft. The air locks were removed, buildings and plant were shipped away, the surface of the dump was graded and other necessary work was done. The actual completion and acceptance of the tunnel and river shaft covered by the contract were made on July 5, 1905, being 95 days before the date set in the contract.

A short time before the tunnel was completed a pipe was driven at the edge of the crib on the engineer's center line to a depth such that it would show in the tunnel when we reached that distance, and it was duly encountered about one foot to the left of the center of the work. From this point we deflected the tunnel so as to bring the shaft connection in its proper location under the center of the crib.

In the month of December, 1904, we had our only difficulty in the work, having encountered a sand pocket on the night of the 16th. This was the only place in the tunnel where the roof

required timbering, and was the cause of the increase of pressure to 37 lb. for three days, after which we returned to the normal pressure.

Previous to the letting of the contract, the engineers had taken borings for the entire length of the work, and our findings corresponded exactly with their reports, the material being a stiff blue clay through the entire length of the tunnel, except the sand pocket previously mentioned. This material was of such a character that semi-circular knives were used to cut it out

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[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1908, for publication in a subsequent number of the JOURNAL.]

STREET ENGINEERING.

By Rutger B. Green, Member of the Detroit Engineering Society.

[Read before the Society, May 24, 1907.]

Let us take a 320-ft. block on a 66-ft. street in some older portion of the average American city and go back to the time when the owners of the adjacent property laid out the street and platted their land into 40-ft. lots.

The amount of thought given to the design of the street was evidently to allow about 44 ft. for the roadway and 11 ft. on each side for sidewalks and tree space, the sidewalk usually taking the 6 ft. next to the fence.

City water was soon needed, to supply which a 4-in. or 6-in. main was laid through the street somewhere near its center and separate lateral service pipes laid to each house supplied. The same was done when sewerage and gas were needed, so that to supply each of the 40-ft. lots on each side of the street with water, sewer and gas required three trenches the length of the block and three trenches across the street every 40 ft. Probably before all of these house services were put in, the street was paved; and services put in after that had to cut the pavement to connect with the mains. If telephone conduits were laid through the street, the pavement had to be cut and replaced by a patch. If steam heating conduits were laid, the pavement was cut to pieces again; and now, whenever sewer, water, gas, telephone or stream conduits need any minor repairs or additions, the pavement is cut up and patched, — poorly patched as a rule. Pneumatic tubes and high pressure gas mains may come later and possibly a subway, which latter would require every foot of piping in the street to be relaid.

The expense of cutting these pavements and the botch patching that usually marks the attempt to replace a pavement over a new trench, suggests that our street pipe engineering is still of what might be called the stone age, or cobble-stone age, more strictly speaking. It did not cost much to tear up and replace cobble-stones laid on a sand foundation, and the concrete foundation that brick and asphalt call for is hardly thirty years old.

To attempt now to remodel the present systems of piping in any down-town paved street might be a greater expense than to put up with the present haphazard arrangement, although a mere pipe gallery in front of a modern office building seems an infinitesimal addition to the cost of the building. It does seem possible, however, to start our new streets with a view to more systematic arrangement for probable future needs, to clean up the rubbish pile by beginning at the outer edge.

Consider, for instance, the water supply of the 320-ft. block having a 66-ft. street. If we have one main somewhere in the middle of the street and run taps to each of the 8 lots on each side, we have 320 ft. of 6-in. cast-iron pipe laid by a contractor in one job with cheap labor, and 528 ft. of lateral service pipe laid by plumbers at different times and different costs, — very different just at present, even when they tunnel a pavement. Suppose, now, that instead of one 6-in. main in the middle of the street we have two 4-in. mains, one at each edge of the street. Then we have the water at the street line for every lot at the expense of only 640 ft. of 4-in. cast-iron pipe laid all at once at contract rates.

Those who prefer algebra will find that if

B = Block length.
S = Street width.
1 = Lot width.

Then $\frac{B}{1}$ = number of lots on each side of the street.

$2B$ = length of trenching where pipes are laid on each side of the street.

$B+\frac{BS}{1}$ = length of trenching with one main down the center of the street and laterals to each lot.

Equating $2B = B+\frac{BS}{1}$.

This is true only when S is no greater than 1, which is rather rare with city lots, showing that under ordinary circumstances the two side mains are the cheaper. This considers trenching length alone. The great advantage of having two mains and no lateral, of course, comes in not having to pay plumbers' prices for the laterals and having no pavements to tear up. There seems to be no good reason why the property owner should not have water, sewerage, gas, etc., delivered to him at the lot line instead of having to dig way out into public property for them.

It is true that the space at the side of the street is used

more or less for store areas. It is city property, however, and should be governed by the city needs. There should not be any great objection to moving the pipes out into the street to the edge of an area, if necessary, provided the area builders pay the cost, which would be a very small increase to the cost of business blocks. When stores come, trees usually go; if the area needs the pipes' space, let the pipes have the tree space. Trees seem like railroads, by the way; we need them badly, but have evidently got to insist on municipal ownership, or government control including regulation of roots.

Where the system of alleys prevails, piping may often be laid through them, the economy depending upon the depth of the block, the fact that plumbing usually centers at the rear of houses helping somewhat.

As large trunk mains are generally laid once and for all on special grades and require few repairs, it would probably be cheaper to lay the very large ones near the middle of the street in addition to having the house mains on each side of the street. It might tend to economical uniformity in piping if the four sides of a block were considered a unit, to be served by small pipe fed from the trunk mains. There seems to be room for a distribution unit intermediate between our present house connections and street mains. It would seem that if a $\frac{5}{8}$-in. water connection or 4-in. soil pipe does for a single house, that a 3-in. or 4-in. water pipe and a 6-in. or 8-in. sewer should take care of one or two city blocks, and perhaps a 2-in. for one block if there is sediment in the water. House connections could be made to the intermediate units, which would be laid at the street edge and be connected up to the large supply mains at every block or two, according as the territory is built up.

There should be state laws governing the suburbs of large cities, so that when annexation is probable, piping laid in the suburbs before annexation will conform to city systems after becoming a part of the latter. There should also be city laws putting the control of all street piping, etc., under the city engineer, so that private companies having franchises for underground work in city streets can be properly controlled and their piping made to conform to the general good of the city.

Now that the cement sidewalk has become the standard, it would seem best for the city to contract for it, blocks at a time, just as the main paving of a street is now done.

There might also be less trouble in getting sites for garbage disposal plants if householders were required to press and dry

kitchen refuse for city collection, thus getting rid of the dripping swill barrel and wagon.

It is the writer's belief that street design is a subject that might well be considered by a special committee of any or all our engineering societies. American city engineers are too subject to political caprice to have time to work out such problems, but it seems to be only reasonable that such a special committee could recommend a street section or sections, quoting which city engineers all over the country could apply for authority to lay out new street work with reasonable assurance that their work would be right, whether the street remained a residence one, or gradually was taken up by business. Certainly, the present indiscriminate and perpetual tearing up of expensive pavements is no more creditable to the engineering profession than tearing a house to pieces to get at the plumbing was to architects until they studied out their present accessible plumbing methods. Street piping is merely plumbing of larger sizes and could easily be made accessible, if not in the older streets, then certainly in new streets, and the rate at which our cities are growing means that, immense as the number of new streets is now, it will be still greater as each successive year rolls by.

DISCUSSION.

Mr. Mattson. — Pingree, a number of years ago, endeavored to bring about a better system of pipes in the city, but owing to inaction on the part of the council, etc., his ideas were never carried out.

Mr. Parks. — I cannot see just why lot owner should build subway to get area. Let the subway be built by the city or some one person and then be owned by him. Lease it to those who want to use same.

Mr. Douglas. — I believe with Mr. Green that something ought to be done in the matter of pipe systems through streets. His system, I think, is a very good one, and ultimately cheaper than the present method.

Mr. Lane. — I think it should be attacked by the board of public works, not only in the outlying districts, but in the down-town section. Lot owners would know just where each pipe is by referring to standard design, thus saving unnecessary digging to find pipes.

Mr. Lang. — What would be done in case of a broken water main, or gas main? Would it not cause a great deal of trouble on account of the close proximity of the other pipes?

Mr. Mattson. — There could not possibly be any more trouble, sir, in the proposed system, than is now the case should a water main break or a gas main break. I think the Association should look into the system of piping through streets in order to determine its value. The sidewalk system suggested by Mr. Green, namely, to have whole blocks laid by the city at one time, is a very good one. I would also suggest that sidewalk builders use stronger cement.

Mr. Douglas. — Sidewalks really are nothing more or less than pavements.

Mr. Parks. — When in New York City I had opportunity of seeing the new subway built, and I have never seen such a mess of tangled pipes before in all my life, showing conclusively that such a system as Mr. Green suggests is a long-felt want.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 15, 1908, for publication in a subsequent number of the Journal.]

DISCUSSION ON MR. FULLER'S PAPER, SEWAGE PURIFICATION TESTS AT COLUMBUS, OHIO.

(Vol. XXXIX, page 67, August, 1907.)

Mr. George A. Johnson. — A long professional engagement abroad made it necessary for the writer to leave America immediately after submitting the report on the tests at Columbus. In view of this fact, and for numerous other reasons, it was distinctly fortunate that the task of reviewing the results obtained during these tests, and of comparing them with experiences elsewhere, could be taken up before this Society by Mr. Fuller, to whom the writer owes an expression of heartiest thanks.

In the discussion of this paper (pp. 122–3–4), two points are raised upon which the writer desires to say a word. These points refer to (*a*) the removal of bacteria and total suspended matter in sedimentation and septic tanks; and (*b*) to the removal of B. coli in coarse-grain filters. Doubt is expressed as to the soundness of Mr. Fuller's statements that the removal of bacteria in sedimentation or septic tanks approximates that of the total suspended matter; and that the removal of B. coli in coarse-grain filters is, in general, proportional to the removal of the total bacteria. Regarding these points the report on the tests states that "in general, the removal of bacteria by plain sedimentation approaches that of the total suspended matter" (p. 98); "the few local data available upon this point show that under normal conditions colon bacilli are removed by contact filters substantially in proportion to the removal of total bacteria" (p. 246); "the results of analysis for the numbers of B. coli of four samples of the influents and effluents of certain sprinkling filters indicated that these organisms are somewhat more thoroughly removed than is the case of the total numbers of bacteria" (p. 299).

To the writer it does not appear that the criticism offered on these points is well founded. It is true that at Columbus the growth of bacteria in the sedimentation and septic tanks obscured the true removal of bacteria. It is equally true that the number of analyses made for B. coli in the influents and effluents of the various coarse-grain filters was small. It must be remembered, however, that such samples as were analyzed were col-

tected with great care in order that the results might represent average conditions, and that the results were obtained by the most thorough determinative tests, and not by the much less accurate and far more unreliable presumptive test by means of which the contrary results recorded in the discussion were obtained.

Experience in the subsidence in water of suspended matters, including bacteria, has shown in most cases that the removal of bacteria is, in a general way, proportional to the removal of the total suspended matter. There can be no doubt that the removal of B. coli in coarse-grain filters is approximately proportional to the removal of the total bacteria. Such filters certainly do not exert a selective action in removing more of one species than of another. One really requires no analytical data to satisfy him that this must be so, and it is a fact that the published evidence all, or practically all, leads to the same conclusion. If there are cases where it does not, it appears to the writer that the fault must lie with the manner in which the samples are collected and the methods of analysis.

Mr. Fuller's review of the whole matter is, in the writer's opinion, in all ways admirable, and his statements are so much in accord with those of the writer on the majority of the points discussed that further specific reference to the paper appears unnecessary except to commend its thoroughness and consistency.

During the writer's travels last year in the Orient and in Europe an opportunity was offered to make a study at close range of matters relating to municipal sanitation, especially with reference to water purification and sewage disposal. It may be that a few notes in this connection will be of interest.

There can be no question that the art of sewage disposal is advancing rapidly in America, England and Germany. Although the universal panacea, the discovery of which has been announced so many times during the past three decades, has yet to be, but probably never will be, found, studies made in recent years by boards of health, municipalities and educational institutions in this country, by the local government board and various municipal boards in England, and by the German and French governments, have done untold good in the effort to solve a problem which as much if not more than any other has to do with the health of the public at large.

In the far eastern countries the solution of this problem cannot even be said to be in its infancy. Methods of disposal of municipal wastes are still of the most elementary kind. In

Japan, where there are next to no fields suitable for grazing purposes on account of the prevalence of bamboo grass, the number of animals is exceedingly small. Natural fertilizers are, therefore, unavailable from this source, and hence, every ounce of human excrement is carefully preserved. This is collected by contractors and sold to farmers at so much per bucket. The farmers store the fresh and semi-liquid material in small tanks and from these draw their supply for distribution over their fields. The odors which arise from these tanks, in which the crude human excrement is stored in highly concentrated form, are particularly offensive for distances as great as half a mile.

Not a little has been said about this method of sewage disposal which appeals to every casual observer as an exceedingly unsanitary procedure. Foreigners hesitate, if not actually refuse, to eat uncooked vegetables coming from such fields. The writer has personally inspected many acres of Japanese farm lands and can say that there is no doubt about the excreta, as applied, getting on to the growing vegetables as well as on to the ground in which they are growing. He was assured by various engineers, however, that the length of stay of the excreta in the storage tanks had everything to do with the destruction of disease germs, and that as applied to the fields it was as nearly as possible innocuous to health. To the writer, however, it appears to be an excellent field for special research, and in his opinion, were the custom done away with of using in this way raw, or nearly raw, excreta of human origin as fertilizer, there would undoubtedly result a sharp diminution of the high typhoid death-rate existing at present in the case of so many Japanese cities. Aside from the pollution of vegetables, it is obvious that a not inconsiderable amount of dangerous polluting matter is washed from these fields into the rivers at time of rains.

In China, except in the coast cities, which are under the control of foreign governments, no advance of a marked nature has been made since the earliest times. The odor of Canton is well known to the traveler, as it well may be. One can smell Canton before it comes within the range of vision, not wholly, it must be admitted, because of the improper disposal of sewage. All over China sewage now as ever goes untreated on to the fields or into the rivers. Human life is not held at a premium in that country, and those possessing the power to exert a bettering influence in the sanitary disposal of sewage evidently look at the matter in a philosophico-fatalistic way, and let things take their unobstructed course.

Even in Shanghai, one of the most beautiful cities of the East, the conditions in the foreign concessions do not in all ways approach the ideal. When driving along the beautiful Bubbling Well Road in Shanghai, on which there are scores of palaces, the writer recalls distinctly seeing stagnant pools of house drainage in the very back yards of some of the most splendid residences. Hong Kong, happily, is located on the steep slopes of a hill, and the opportunities for natural drainage into the harbor are all that could be desired.

In India, something has been done, but there remains much to do. Quite recently an excellent piece of work in Bengal has been completed by Dr. Gilbert J. Fowler. The results of this work have recently been published.

Here, as in all these eastern countries, the sanitarian has to cope with ignorance, religious bigotries, or at the very least a sublime indifference. The waters of the Ganges and its main tributaries, for example, are not what could exactly be called potable, as the extensive water filtration works of the city of Calcutta bear witness. The majority of the natives of the poorer class are sublimely indifferent to the fact, however, and a familiar daily sight at the bathing ghats on the Ganges is to see hundreds of natives performing their ablutions together, included in which operation is a very thorough rinsing out of the mouth with the water in which the multitude is bathing. Not satisfied with this, the bather on departing takes away with him a vessel of the same water for future use. The vessel is usually of copper or brass, so if there is germicidal virtue in copper receptacles, it may be that the otherwise almost inevitably evil consequences are defeated in some instances in this way.

More or less similar conditions are found at Cairo, where the water supply is drawn from a series of wells along the banks of the Nile. Native water venders, however, may always be seen on the banks of the river within the city, filling their goat skins with river water for the benefit of the poorer classes, or to be made into the popular "limonade" so picturesquely distributed, two glasses for a piaster, about the city. This water is not immaculate as regards purity, as may be inferred.

At present Cairo has no sewers, mainly because it hardly ever rains there, but recently Mr. James, one time municipal engineer at Bombay, and the author of several engineering works, has been retained by the city to lay out a complete system of sewerage. It is understood that purification works are to be included in this system.

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WATERPROOF ENGINEERING.

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[Read before the Boston Society of Civil Engineers, October 16, 1907.]

IT is one thing to build a structure and another thing to make it sound and safe. "Waterproof Engineering" means the sanitariness or healthfulness, the soundness, the safety, the preservation and the durability of structures. It means the fighting of moisture.

Waterproof engineering is based on three fundamental principles:

First. Design.

Second. Method and materials.

Third. Application.

The general subject is too broad to be covered in one evening's discussion. This paper will, therefore, treat only of the second and third principles, viz., "Method and Materials" and "Application."

All efforts in the waterproofing of structural work are divided into two main, totally divergent lines, *i. e.*,

First. Treating concrete to make it, in itself, impermeable.

Second. Protecting concrete or masonry with something *apart* therefrom, to waterproof it.

In other words, Shall water reach the concrete or shall it not reach the concrete? The real point at issue, therefore, is one of method, which must be first settled before we can intelligently discuss the question of materials. First, therefore,

determine the method, and the production of the proper materials will settle itself. We will consider the two above-described systems separately.

1. Treating Concrete to Make it, in itself, Impermeable.

Treating concrete to make it in itself impermeable rests upon two methods:

First. Mixing certain chemicals with the concrete to make the concrete, in itself, impermeable.

Second. Applying a cement plaster or wash on the concrete to harden its surface.

The ingredients generally used are lime, silicate, soda, lye, soap, alum, etc.

One of the present chief difficulties in concrete work is to obtain concrete properly mixed in the field. This difficulty, instead of being lessened, will be greatly augmented by the mixing of chemicals with the cement, with the idea of making the concrete watertight. Certainly, to obtain a concrete so perfect as to be perfectly watertight will be a much more difficult thing than to obtain ordinarily sound concrete. In either case there will always exist zones weak in quality and density. There is also the added danger of the uncertain effect the addition of the chemicals will, in time, have upon the tenacity and the durability of the concrete itself, and especially upon the embedded steel. This is all experimental, and not tried and tested, waterproofing.

The objections to the second method, *i. e.*, applying a cement plaster or wash to the surface of the concrete, are too numerous to mention here. It is poor judgment to depend upon but one layer of any single thing, which in this case is an inelastic cement plaster or a thin, almost imperceptible, wash, as the sole waterproof protection of any structure. This, aside from any consideration of the splitting or cracking of the cement plaster, or that but one infinitesimal pore imperfectly closed, by permitting the entrance of water, which would soon spread, would make valueless the balance of the washed surface. Such treatment is not even consistent with the doctrine of *similia similibus curantur*, because we are not curing like with like, but adding a bad thing to a bad thing.

There is a fine distinction between testing concrete for strength and testing it for watertightness. The difficulty is that these two principles are confounded by experimenters in attempting to make concrete in itself watertight.

Assume for the moment that concrete *per se* may be made impermeable. If this impermeability will not prevent cracking, and as cracking will destroy the value of impermeability, why attempt to make concrete impermeable? Granted that even limited impermeability, as it were, is a desirable quality, is there not needed, however, something additional for dependable and perfect waterproofness for general conditions and practical work? There is no more important problem before the engineering and architectural professions than this one, — Whether concrete can, in itself, be made watertight.

Waterproofness is not what it is to-day, but years hence. Because a briquette, or cube, or box of specially-treated concrete remains watertight in or out of a laboratory for one or twelve months is no warranty that concrete can be made permanently watertight for practical purposes. Assuming even that there can be had concrete in monolithic form so perfect in texture and mixture as the specially-prepared laboratory sample, masses of concrete in the open are subject to conditions, especially in this latitude, impossible of ascertainment and test in a laboratory sample: to extremes of heat and cold, to settlement, to contraction and expansion, to earth tremors, both natural and artificial, — resulting in fractures, the opening of pores, etc., a process which certainly does not decrease with the advance of years. Water will come through concrete in time. It will take longer to work through so-called watertight concrete, but it will eventually come through it. Otherwise it would be contrary to the law of physics and nature. The same principle applies, in greater course, to cement plaster and hardening compounds for the surface.

We have seen water drawn up, through capillarity, 15 or 20 ft. by concrete. We have also seen water percolate through concrete over 20 ft. thick. It may take two or three years to do so; meanwhile, the assumption is that the concrete is fairly watertight. When the concrete thus becomes damp, wet, and saturated, it is almost impossible to eradicate the moisture. If the moisture freezes, expanding one tenth its volume in so doing, it requires no stretch of imagination to calculate the effect upon the concrete or masonry. Enough water will be taken in through a crack before the crack is filled to attack and injure the steel.

Again, many engineers believe that by increasing the steel reinforcement the cracking of concrete will be prevented and the concrete also be made watertight. The speaker has long

contended that embedding steel in concrete may or may not injure the concrete. We appreciate that this is a rather bold assertion. To elucidate this theory, and, in fact, to better understand the deeper, more scientific, more fascinating side of waterproofing engineering, we beg you will indulge him in a brief analysis of moisture.

In this connection the speaker will draw a comparison between concrete with steel embedded therein and a geological stratum. Moisture is creative and it is destructive. Of all forces it is the greatest. Nearly two thirds of the globe is water — a wise provision of nature. Moisture generates heat and, in the generic sense, there is no heat without moisture. Rust formation is an explosive force even greater than that of freezing water. Iron is one of the most important and the most abundantly distributed chemical elements in nature; purposely so, if we may so express it. Iron has a wonderful affinity for moisture, which it will draw through many feet of rock and soil and, eventually, deep down into subterranean rivers, lakes and seas, of fresh or salt, hard or mineral, cold or boiling water, which in its further course of percolating through the earth's varied strata originates chemical action, — heat, ignition, combustion, — the expanding, pent-up steam and gases finally bursting in a volcanic eruption.

The laws of nature are inexorable and always remain the same no matter in what new form they may be expressed. In the pride and glamor of our marvelous artificialities we sometimes get so far away from natural law or first principles that we must go back to locate ourselves, as it were, and start anew.

For instance, in taking sand, stone, lime, cement — all earthy matter — and forming them into a hydrated material, to which we then add iron, we are simply forming a typical geological stratum, all the elements therein (particularly the steel) having, in a greater or less degree, a strong affinity for moisture. We incorporate the steel to strengthen the cement, or the cement to protect the steel, but fail to take the next step forward and protect the cement. Adding more cement to it, in the form of cement plaster, is not adequate protection. What is the natural result? Moisture is readily absorbed by the cement, either by capillarity or through cracks, while the greater affinity of the steel alone would, and does, of itself, draw moisture through 2 ft. of cement. The moisture in passing through the cement takes up certain salts injurious to the steel. When the moisture reaches the steel, chemical action ensues,

heat is generated through decomposition or corrosion, the pent-up gas (liberated hydrogen) escaping by bursting off a brown, infinitesimal, volcanic cone, which we call rust.

And thus we have expressed, only in a different way, the same changeless natural law underlying the volcanic eruption. We are at the exact point in the circle whence we started, only, spiral-like, a little higher up. In both cases, *i. e.*, in the earth and the cement, the iron is imbedded and out of sight, and no one knows what degree of change in it has happened. We do know, by the natural law, that some change is occurring to the steel imbedded in the cement. We know that steel, imbedded in cement and kept dry, will indefinitely retain its purity and strength. We know also that moisture, reaching the steel, creates corrosion. The immediate effect is to destroy the bond between the steel and the concrete. The heat and expanding gas from decomposition (which is progressive) press the cement away from the steel. There then no longer exists, in fact, steel-reinforced concrete, but the very opposite, and a menace to life and property, which may eventually end in a collapse. If there is a particle of iron in the plaster on the ceiling and walls of this room, it will make itself apparent by a brownish, raised spot or scale as the result of moisture in the air attracted by and decomposing the iron.

It is said that no one with an imagination will commit a crime. It seems incredulous if what has been just said be true, that any one with an imagination would add to cement or concrete in the mixing; salt, iron, slag or cinders. The same may be said of unthinking engineers and architects who would waterproof by using cement-plaster compounds. Moisture percolating through cinder-concrete will form what is commonly termed lye, which will soon eat through any steel wire, rod or girder. Because of its lightness, however, but without regard to its chemical fitness, cinder concrete is extensively used for floors — the very part of a structure most apt to collapse. Waterproofing concrete floors is a rarity, on the assumption that they are sufficiently watertight. Possibly so, but it is not the quantity of water which flows over or evaporates from the floor surface, but the small quantity which, from time to time, reaches below the surface, where it remains longer than elsewhere and is unseen, that is decaying the imbedded steel.

Waterproofing arches is still widely looked upon as a wasteful expenditure, while the waterproofing of the masonry or concrete encasing the steel columns of our tall office buildings is considered the essence of refinement.

Steel-reinforced concrete is yet but an experiment. Nor do we know the life of the modern steel office structure. One thing is sure: that the security and life of its steel skeleton depend upon how far the columns supporting the structure are at their *base*, rotting from electrolysis or moisture. We do not know, because we do not see, but that they *are* decaying is true. While painting exposed steel tends to protect it, paint prevents the bonding of the steel and cement. The life of a masonry structure is indefinite. This will better explain our first statement that imbedding steel in concrete or masonry may or may not be dangerous. It is certainly safer that steel be always open to observation and minute inspection, as, for instance, on a bridge. As gangrene in the flesh or bone will kill the living organism, so will diseased, decaying steel tend to eventually destroy the cement in which it is incorporated. Evidence in this direction is abundant if we can stop long enough in our rush to accomplish things to carefully consider it.

In the proceedings of the twenty-eighth annual convention of the American Institute of Architects, 1904, in a discussion regarding steel cage construction, Mr. Geo. B. Post, the distinguished architect, said:

"I want to say one or two words more. I meant the statement in the outset in regard to steel cage construction and its durability, not to a possible construction made with the greatest possible care, but to construction as I have seen it going up in the city of New York during the last two years, where the iron columns were given a very light coat of paint, very little attempt made to protect the joints. I presume that the great mass of joints will remain for a great period perfectly sound and safe, but the several hundred bearing joints in a building put up without any great care, put up, it seems to me, with a good deal of recklessness in a great many cases, with no protection except 8 in. of ordinary brick-work, I don't believe they will stand for any serious length of time with perfect safety. I don't know if you gentlemen have had the experience with brick walls that I have. I have seen the water in a northeast storm in the city of New York go through a 4-ft. brick wall and run down on the inside of its surface as though there was nothing there — a wall 150 ft. high, exposed to a northeast gale, the water went through the 4-ft. wall at the second story and ran down on the inside, the wall being unpainted. The condition of a beam encased in cement and in a foundation is a very poor guide for what will occur in a joint on a flat, exposed wall, with only 4 to 8 in. of unpainted masonry. Every time that a storm comes, that brick work becomes soaked with water and will remain soaked for a considerable time. I should not hesitate, individually, using great care, to put up steel cage construction of any

height, but I think that it is a matter in which we should be exceedingly careful, and I do not believe that the construction of a great many buildings which I have seen go up is of a character which will stand any longer than the beams which I took from the first tier of the Times Building when I made the alterations. The ceiling was 20 ft. high; there was running machinery in it; it was dry, clean and well-kept. There was no apparent moisture, but many of the wrought-iron beams in the ceiling had, as I say, entirely lost their integrity and strength. I don't think, if they had had steel or cast-iron beams, that the result would have been the same, but unless the greatest care is taken to prevent corrosion of the metal, there will be trouble."

In further and stronger evidence there is submitted the following extract from a very recent report (dated September 11, 1906) to the Structural Association of San Francisco, by a committee appointed to make an examination of certain cases of corrosion of metal in cinder-concrete floors:

"The cinder-concrete is somewhat porous, with occasional voids, and also contains coal, from dust up to lumps 0.75 in. diameter. Rust spots occur in the concrete, and where such spots are in contact with the metal, the corrosion is severe. The rust spots are sometimes an inch across, quite soft and easily removed by the finger nail. Occasional splinters of wood occur in the concrete, which shows that the heat was not severe, as the wood is not charred. From the position of the floors it is certain that no water has reached the concrete since April 18 and that the corrosion was prior to the fire, but it appears to be more marked where floors have been exposed to rains since the fire. The corrosion is irregular in amount. In some cases the expanded metal is only slightly rusted, and in places it is entirely destroyed; several places were noticed where a small semicircular patch had been removed from the edge of a metal strip; also at times it crossed the surface of the strip in a line, which suggested that it followed a surface crack in the metal. There seemed to be a tendency to corrosion at certain points in the diamond mesh, which would indicate that the metal had been strained in the process of setting and expanding, but there is not positive proof of this.

"The extent of the corrosion is great enough to seriously endanger the safety of the floors, and it is not probable that the floors would have supported their loads more than one to three years longer."

The committee recommended that their association try to have the building laws amended so as to exclude the use of cinder-concrete in floor slabs or for fireproofing. The protection of the floor from moisture or water, however, seems never to have occurred to the committee.

We do not want to get away from the initial point in this paper, namely, that in the formation of steel-reinforced concrete we are simply transferring certain chemical elements with no change in principle, and must needs go a step further. The suggestion occurs, therefore, that we must treat the new form of the structure as we would a living thing — a thing that moves — if we expect that particular thing to be long of safe service; otherwise we revert back to the crudity of the same first principle, linking the eruption of the volcano with the formation of rust. So considered, therefore, we again inquire, Is or is not steel a menace to concrete?

We need not dig deep into chemistry or physics to substantiate the facts. We need only take the overt fact, the evidence of our eyes, based on common sense.

If moisture is the thing, as it undoubtedly is, then moisture is the thing to be counteracted. Therein lies the prevention. The real importance of waterproofing, therefore, is not simply in keeping water out of buildings, but in protecting and preserving the imbedded steel.

Another very serious factor is this: *Concrete is not an insulator and is not proof against electrolysis.* The New York *Herald* of Sunday, August 4, contained a page-illustrated article in which the above assertion was made so startlingly clear, supported by valuable tests, that it is well worth reading. If so-called "water-tight concrete," in itself or by the addition of cement plasters or similar compounds, is not proof against electrolysis, no estimate can be made upon the future damage which the use of such methods will entail.

The real theory of waterproofing is what? It is insulation. It means to separate, to get away from. Insulation and waterproofing are correlative. There can be no natural waterproofing without insulation. It is a natural law. Therefore, any other waterproofing would seem to be erroneous — how could it be otherwise?

After due consideration, therefore, and recognizing the fact that so-called "water-tight concrete" or cement plaster or washes are *not* in themselves insulators, does it not seem necessary and logical that we seek some other method of waterproofing than to rely upon water-tightness in the concrete itself; that we get away from the concrete and provide something between the concrete and moisture, and between the concrete and the earth, to so protect and *insulate* it that water will not reach the concrete, whether it cracks or not? This brings us to the consideration of the second method, viz.,

Protecting Concrete with Something apart therefrom, to Make It Waterproof.

Under this head come those materials and methods for preventing water from coming in contact with the concrete. Practically the first efforts in this direction were to coat the surface to be waterproofed with hot coal-tar pitch or asphalt, which, however, when set and cold, cracked and separated with any settling or cracking of the masonry. Burlap was subsequently used to reinforce the pitch or asphalt, without, however, preventing them from cracking, and the burlap, being of itself not waterproof, did not give waterproofness. Later on, there came into use for this purpose tar paper, which, however, lacks pliability and tensile strength. Tar and tar paper have been extensively used for waterproofing in the past, simply because there was nothing else open to the profession. It was not until recent years that any serious effort was made to place waterproofing on a scientific basis and to make materials specially adapted to the various conditions, materials which would not become brittle or be injuriously acted upon by water, the salts in the earth, alkali in cement, etc. The result of this specialization has been to greatly improve methods, and to open to the profession products for difficult work and special conditions, considerably in advance of old-school materials.

There are also used for waterproofing, mastics composed of coal-tar pitch, or asphalt, mixed with sand or torpedo gravel, resembling somewhat, when finished, an asphalt pavement. Mastics on floors, especially on bridge floors, where there is considerable vibration, soon separate from walls, steel columns and girders. If the mastic is made soft enough so as not to crack in winter, it becomes too soft to bear the load of traffic in summer. The chief objection to mastics is that they crack clear through, with any contraction and expansion or cracking of the masonry or concrete surface, of which they become an integral part when applied hot thereon.

Specifications also frequently require that the interior surfaces of foundation walls and floors shall be given one or two coats of some waterproofing paint. The paints might be excellent materials in themselves, but their use for such a purpose is a sheer waste of time and money as they cannot possibly prevent, for a number of obvious reasons, the percolation of water through the wall, or protect the imbedded steel. There are also now on the market a number of what are termed "textile" waterproofing materials, which, on examination, will be found composed, in many instances, of simply burlap, *i. e.*, ordinary

commercial bagging. The fiber is vegetable, is extracted from the bark of trees and is very perishable, especially in underground conditions. The apparent strength of such materials misleads one into using them, whereas strength *alone* is not, by any means, the first essential in a waterproofing material. These saturated textiles or baggings are, in a measure, going backward to the old-school method of incorporating burlap with pitch or asphalt to reinforce it as steel reinforces concrete. There is a clear distinction, however, between the principle and results to be obtained in reinforcing concrete with steel, and reinforcing waterproofing with burlaped textiles. The two should not be confounded. Otherwise it would be advisable to reinforce the bitumen with copper mesh. The treated or saturated burlap is no more waterproof, especially for water-pressure work, than when originally used to hold pitch or asphalt on a wall. This can be easily tested by placing a single sheet or thickness of the treated material under the slightest water-pressure, when it will be found, within a few hours or days, that water easily passes through the interstices of the material. A woven fabric has never proved superior for waterproofing, even though it be canvas, because the fibers pull against instead of with each other, resulting in the opening of the interstices and the usual splitting of the fabric.

The best material is unquestionably a strong, fibrous felt, made in itself, *i. e.*, in one sheet, absolutely impervious to water by a process of saturation and coating with materials specially adapted to withstand the injurious action of water, and particularly all underground conditions. It is then practically an impervious membrane or skin through which, of course, in one sheet, water will not pass. As many layers thereof as the conditions require can be then cemented or veneered together with a waterproof bitumen-cement, not too weak or hard and brittle for the felt, but as strong and elastic as the felt. This forms a waterproof stratum so strong, tough and pliable that, without injury, it can be readily pulled, bent, turned, twisted, etc. Whether in a building foundation, covering the floor of a bridge or enveloping a tunnel,— it readily conforms to the final conformation of the surface waterproofed, from which it is practically *apart* and which it insulates and protects under all conditions, settlement, jars, shocks, cracks, expansion, contraction, heat, snow, ice, water, etc.

The speaker some time ago termed this " the membrane method," and firmly believes it the basis for the development of

a perfect waterproofing. It is not, therefore, primarily a question of material, but of method.

We previously advanced the theory that our structures should be treated, in the waterproofing sense, as things that live, *i. e.*, things that move. We would again, therefore, go back to locate some first principle of natural law as a guidance, because there is nothing made by man that its prototype in some form is not somewhere in nature. No man ever devised an insulation for the most intricate electrical machinery as perfect as the insulation of the human brain — the dynamo of the universe. In seeking a guide, therefore, in our present problem, we find throughout nature no waterproofing which is hard or set or vitreous, because nature waterproofs only living things (things that move), not dead ones or inorganic ones, which do not require it, but, by moisture, heat and decomposition are resolved back into carbonate of lime. Therefore, all things that live and move require, and are by necessity protected with, a flexible, elastic skin, yielding to growth, movement, action. Therein lies the origin, the first principle of waterproofing, natural or artificial. Can any other principle be right?

In the very beginning of germination, nature begins to cover, insulate and protect, with an elastic film, skin or membrane, the life germ. This law prevails through the whole line of plant and animal life, from a grain of wheat up to a mastodon. Puncture this protecting skin or membrane and there immediately ensues decomposition (or corrosion) in the exposed flesh. So long as the plant or animal lives, whether one or a hundred years, this yielding membrane perfectly protects. We ourselves take the tough hide and the fine elastic skin of animals to protect our feet and waterproof our hands, both our own and the artificial protection readily yielding to every move of the foot or hand.

If a chicken came forth in a coating of soap and alum, its usefulness would end with its appearance. Nor do we waterproof our feet or our hands by immersing them in a bath of cement, which would make them set, rigid and useless. Yet, is this not essentially what we do when we would protect and waterproof our structures, which must settle, contract, expand and *move*, with an injection of hardening fluid to embalm them, thus preventing instead of providing for the natural functions of the masonry or concrete, and also imperiling both the waterproofness and the usefulness of the structure? Obviously, therefore, a natural waterproofing is one which — skin, hide or

membranelike — yields to the natural contraction and expansion of the structure and protects it by preventing water from reaching it. If, therefore, the skin or membrane theory is logical, natural and right, it then simply remains to develop that theory and to scientifically perfect the materials necessary for its practical success.

Considered in this light, *i. e.*, following the membrane idea, and coming down to the actual work of preventing water from reaching the structure and insulating it, we would submit the following observations and rules:

Practical Application of Waterproofing.

First. No waterproofing, especially for difficult and water-pressure work, should be undertaken when the temperature is below 25 degrees fahr.

Fifty per cent. better work can be done when the weather is warm. In cold weather the felt sheets are difficult to handle, the hot bitumen-cement chills and congeals too quickly, especially when it comes in contact with a cold wall, and it is difficult to obtain the perfect cohesion of the different felt layers.

Second. Allow sufficient time, room and accommodations in which to properly apply the materials.

The reverse of this rule, however, is the common practice. No other part of construction work depends more upon the perfection of details than waterproofing. Yet there is no part of such work which receives so little appreciation and consideration. To not make every provision for facilitating waterproofing work is a great mistake. No matter how conscientious a workman may be, he cannot, for example, do good work on a wall from the outside if the excavation is not wide enough from the wall to give him room in which to work, or on the inside of the wall if he has scarcely light or arm room, and is crowded upon by workers in brick, in cement, in stone, in steel, etc.; nor on the roof of a subway, under railway tracks, if there is not sufficient head and working room between the roof of the subway and the base of the tracks, etc. This lack of consideration, in not providing time, room and the necessary facilities, and in allowing contractors to apply the materials in any haphazard way, so long as the materials are applied, is the real cause of so many past failures. Nothing pays better than good waterproofing, and nothing is more disastrous than poor waterproofing. Once water gets behind waterproofing, no waterproofing would have been preferable.

Third. Design the structure to properly receive waterproofing.

The design will either make impossible proper waterproofing, or will invalidate the best materials after they are in place. The line of waterproofing should be adapted to the nature and purpose of the structure, and be logical with the point of water-pressure.

As an example of a faulty design, there is submitted the following sketch, frequently used in trade pamphlets of waterproofing materials. It has, in fact, been adopted in the department of buildings in one of our largest cities, and shows how easy it is to officially endorse and follow a bad principle.

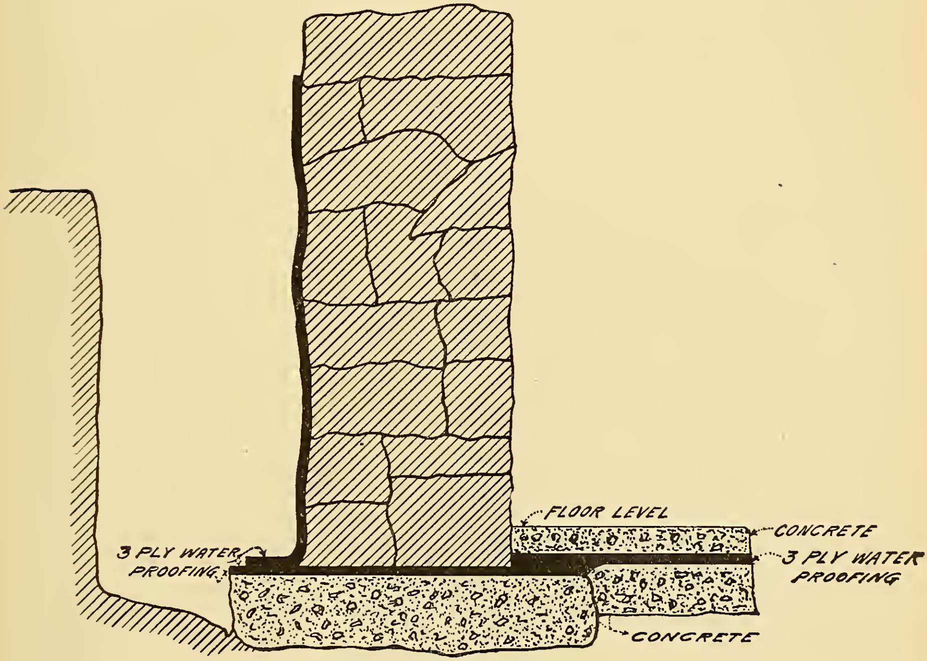


FIG. 1. A WRONG DESIGN.

Fourth. Specify always that the waterproofing shall be done only by experienced and skilled labor.

Roofing, for instance, is not waterproofing. An excellent example of this is shown in Fig. 2, in which "waterproofing," is applied to the back of a retaining wall. The contractor, a roofer, was so proud of his work that he had the picture taken to illustrate it. It requires no trained eye to see that the surface of the retaining wall is, in the first place, too rough, and is not

rightly smoothed, to waterproof; that the corners of the wall and the edges of the steps are round and badly broken instead of being neat and square, making it almost impossible to fit the layers of felt around same. The waterproofing itself is slovenly and irregularly applied, underlaid with air pockets, not properly lapped or smooth and tight. No skilled waterproofer would, at the outset, have applied the materials to such a surface. He would have refrained from doing so until the surface was properly prepared. This is also a case where possibly the engineer did not himself know — but engineers cannot be expected to know all things.

Fifth. Thoroughly protect the waterproofing during and after application.

The average laborer is no respecter of waterproofing, especially an elastic waterproofing, and will walk on it, roll wheelbarrows over it, throw tools, lumber, brick, stones, cement and débris thereon, to its serious damage.

After arches are waterproofed it is a common mistake in placing the fill to not begin the fill at the base of the arch, but to dump it on the crown. The fill thus often breaks through and tears or strips the waterproofing from the arch surface. It is false economy to not always permanently protect waterproofing with a layer of brick or cement mortar. Examples of such a protection are shown in the accompanying figures:

Fig. 3 shows bridge floor waterproofing protected with hard brick, laid flat and fairly close in a thick coating of the hot bitumen cement, the joints being filled with the cement, with which the bricks are also finally coated. Over the brick is placed sand or stone ballast, in which rest the ties for the rails.

Fig. 4 shows another method of protecting the waterproofing. The man in the middle foreground is placing cement mortar directly over the waterproofing; while the man beyond him is laying brick on top of the cement mortar. Immediately to the right of the brick layer is seen another course of cement mortar which has been placed over the brick.

Fig. 5 shows the protection of wall waterproofing by a 4-in. course of brick laid against the wall in cement mortar.

Fig. 6 is an example of the best method of applying the felt, especially on flat surfaces. It shows the felt being rolled after the mop which spreads on the hot cement. Rolling presses out air bubbles and insures better sticking. A workman follows, rubbing and pressing the felt over the entire surface to insure thorough adhesion to the under layer. Just letting the felt fall

Fig. 2. A Case of Poor Waterproofing.

Fig. 3. On Flat Work.

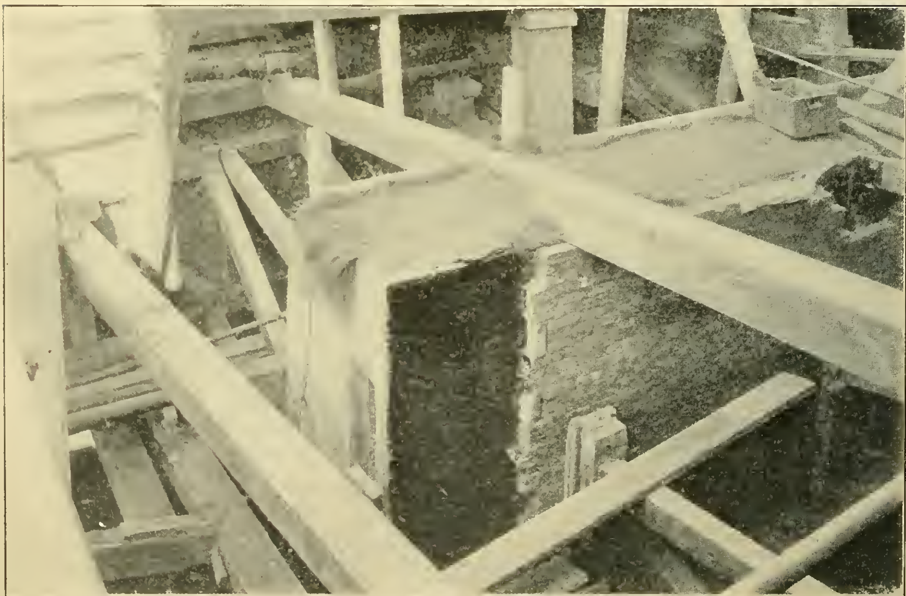


Fig. 5. On Wall Work.

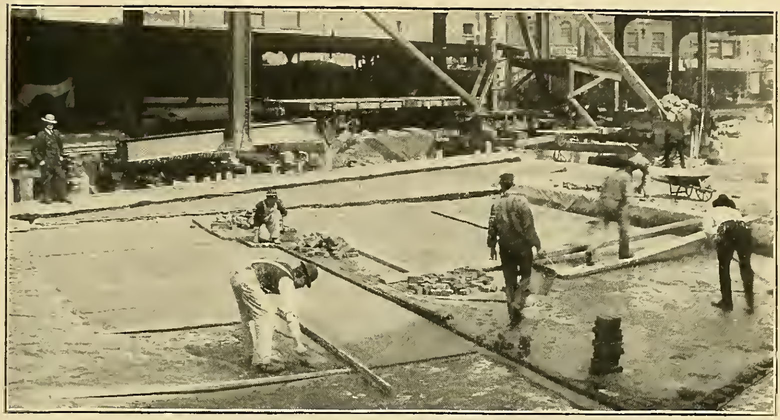


Fig. 4. On Flat Work.

Fig. 7. Preparing Surface.

Fig. 6. Rolling Felt after Mop.

Fig. 8. A Saved Viaduct.

flat into the hot bitumen cement is *not* rolling it into the hot bitumen cement.

Fig. 7 shows a bird's-eye view of the series of arches, on one of which the waterproofing was shown to be in process in the previous picture, No. 6. The man in the middle foreground is trowel-smoothing the concrete surface for the waterproofing.

This concrete viaduct (Fig. 8), with its graceful arches, was erected in 1902 without being waterproofed. The result was that within the short space of three years the condition of the viaduct was such that, in order to save it, it was necessary to remove a greater portion of the top surface and place thereon waterproofing which should have been applied in the first instance. This condition was brought about by the weep pipes at the bottom of the reservoirs between the arches filling up from cementation, permitting the reservoirs to fill with water which percolated in streams through the concrete. The water in the reservoirs, and that which saturated the body of the concrete in the arches, froze in the winter, causing the arches to spread and split, thus endangering the entire structure. Even at the present day a great many engineers and architects look upon the waterproofing of viaducts and arches as unnecessary. In contradiction, can any evidence stronger than the above be cited? A membrane or stratum of waterproofing over the arch under the wearing surface not only prevents the unsightly discoloration of the arch, but preserves both its beauty and integrity.

Sixth. Inspect waterproofing at all times during application.

See that the materials as specified are used, and also that they are themselves up to standard; that the work is done carefully and skillfully, particularly in the out-of-the-way small difficult places; that the laps are not made 22 in. when they should be 24 in.; that the hot cementing material is applied, not one fourth or one half, but the entire width of the lap; and that it is applied *hot*, quickly and thoroughly; that full, clean and well-protected connections are provided; that the waterproofing is well protected at the end of the day's work; that no work is done except in the presence, and by the approval of, the special inspector appointed over the work.

If the inspector is himself not thoroughly skilled in waterproofing he is of no value. He might be an expert in steel or cement or caisson work, but without the right experience in, and the knowledge of, waterproofing, the waterproofing men under him could easily deceive him in important details of the

very thing which is to make permanently safe and valuable the steel and cement. If the waterproofing is very important, expert direction and supervision should be obtained.

Seventh. Do not depend on guarantees.

The speaker has always contended that a waterproofing guarantee is practically worthless. A roofing guarantee is of value because the conditions are entirely different. In roofing, the cause of and responsibility for leaks can be easily settled. Seldom, however, is there any recovery had under a waterproofing guarantee. Bonding companies are averse to supporting waterproofing guarantees because of the high risk. It will be found on close analysis that bonded guarantees do not, in fact, guarantee. Such, for example, is a bonded guarantee reading that the structure or surface to which the waterproofing is applied must remain " sound and stable."

The very purpose of waterproofing is to waterproof the structure or surface in the event of its *not* remaining " sound and stable." Such a guarantee, of course, means nothing, except that the bonding or other company assumes no risk, but shifts it to the owner of the structure, who himself then guarantees that his structure or wall will not crack or injure the waterproofing. The waterproofing should accommodate itself to the wall instead of the wall accommodating itself to the waterproofing. The best guarantee is work, intelligently, skillfully and honestly executed by a concern of reliability and reputation.

A strong case in point is a recent decision on a waterproofing guarantee by the United States Circuit Court of Appeals, Third Circuit, 144 Federal Report, 942. In a contract for the foundation of a building the specifications, after describing the waterproofing materials to be used, stated: " The whole to be made perfectly water-tight and guaranteed." On the completion of the foundation it leaked and payment was withheld from the contractor. The contractor contended that he had strictly followed the specifications and was not accountable for the result of the plans. The court upheld the claim of the contractor.

Eighth. Do not use a set or standard specification.

Each design must suit the exact conditions, and each specification must exactly suit the design. Using a set or standard specification frequently offsets the very purpose desired. It results in the customary but very serious mistake of placing the waterproofing details on the contractor. A contractor will

apply anything that is specified, and, as a rule, is interested only in getting it applied as quickly as possible. Speed in waterproofing is undesirable and dangerous. The specification as to waterproofing, particularly in important work, should be clear and to the point in every detail. It should make the contractor responsible only for the proper application of the materials under the close observation and approval of the engineer.

In the final analysis, the sanitariness, soundness, safety, preservation, usefulness, symmetry and beauty of any structure depend upon protecting it against the destructive action of moisture.

[Note.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1908, for publication in a subsequent number of the Journal.]

THE APPRAISAL AND DEPRECIATION OF WATER WORKS AND SIMILAR PROPERTIES.

By William H. Bryan, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 6, 1907.]

This subject involves many intricate questions, and although it has been much discussed in recent years, it will, in the author's judgment, repay further study.

It may perhaps be of interest to add that at the time of preparing this paper the author had in hand the appraisal of a water system, and occupied the unusual position of having been selected by both parties in interest, the city and the company. He was particularly anxious, therefore, to have before him a clear, concise and just statement of all the considerations which might fairly affect the case from every possible standpoint.

Changes of ownership often occur in industrial or public utility plants. Frequently a water-works system or an electric-light plant is taken over by the municipality in which it is located. Private plants often pass from one ownership to another. Both public and private plants not infrequently desire to raise money by issuing bonds upon their properties. Sometimes, as in Illinois and California, the rates for service are based on the investment in plant; not infrequently such appraisals are desired as a basis of taxation. When questions of this character arise it becomes necessary to ascertain the value of the installation. As such appraisals are usually made by engineers, it is important that we have a clear understanding of the considerations involved.

The form of procedure is usually determined by the franchise or other agreement existing between the city and the company. Such franchises are usually granted for specific periods, — in Missouri for twenty years. The city often reserves the right to purchase at the end of five, ten or fifteen years, and almost invariably at the end of the franchise period. Usually the city must give ample notice in advance of its intention to purchase. The appraisal is generally made by a board of three, one selected by the city, one by the company, these two selecting the third. If they cannot agree, it is often provided that some court of

local jurisdiction, or the governor of the state, shall appoint the third member. It is sometimes stipulated that should the company fail or refuse to appoint its representative, then the court shall appoint a suitable person who shall act on behalf of the company. These appraisers are usually required to be experienced and disinterested parties; often they must be non-residents. The finding of the majority of the board is usually conclusive, and the city has the right to purchase at the price fixed. Failure to exercise this right acts as a waiver until the next purchase date. If there has been no purchase at the end of the franchise period, the usual provision is that the franchise must be renewed. In some cases there must be a revision of public and private rates at that time. In some franchises there is no provision as to the relations which are to exist after the expiration of the franchise in the event that the city does not purchase. In no case which has come under the author's observation has it been compulsory for the city to purchase at the price fixed, although the company was obliged to sell if the city chose to buy. If the city does not exercise its option, then the franchise and contract continue, except when the original franchise period has expired, when serious complications often arise.

In some cases it has been claimed that the city council has no power to bind the people for longer than a fixed period, — usually twenty to thirty years,— even when such action has been confirmed by vote. This may mean that the provisions intended to cover the situation at the expiration of the franchise period — those governing the sale of plant, or renewal of franchise — are non-enforceable. When one or the other of the parties thinks it for his interest to take this position, the situation is indeed "up in the air." As a rule, however, the courts have refused to sanction anything which savors of confiscation or of compulsion, and they will not usually allow the installation of a competing system. In the end, the city usually takes the existing plant, but is not required to pay a fancy or "boosted" price for it.

The wording of the franchise is often indefinite as to what value is meant and how it shall be arrived at. Common expressions are "the value," "the cash value," "the then cash value," "the appraised value," "the fair valuation" and "the fair and equitable valuation." Some special cases which have come under the author's observation are: "All values of the property"; "the fair valuation of said works, and all property connected therewith"; "the fair value plus such actual damage

as the company sustained by reason of the sale" ; "fair valuation, to include works, privileges, property and the productive value"; "the fair and equitable value, *i. e.*, the actual value of works, lands, buildings, machinery and equipment, including franchise"; which latter, I confess, was a "stunner." In one case 10 per cent. was to be added to value of the plant as found by the appraisers. A well-known case in Maine was conducted under the right of eminent domain. The appraisers were to be appointed by the court and were to fix the "fair, equitable and just value of plant, property, franchises, rights and privileges." In this case either party was authorized to apply to the Supreme Court for instructions, and this being done, the court laid down an exhaustive and well-digested set of rules governing all aspects of the case, which to this day form valuable precedents. In many cases it is stipulated that no allowance is to be made for the "franchise" value, and when this is the case it greatly simplifies the situation.

What is meant by the "value" of a plant, that is, the physical features, in this connection? Undoubtedly we mean such an amount as will fairly measure its ability, at the time of appraisal, to perform the work for which it was installed. This, of course, bars from consideration its second-hand, forced sale or scrap value. It has also been expressed as "the value to a seller who is willing, but not compelled, to sell, and the value to a buyer who is willing, but not compelled, to buy." As in any other trade, both sides must be satisfied. Practically the same conditions should govern as if one private individual or corporation sold to another.

Above all, the value must be a fair one. There should be no "hold-up" methods employed by either party, as is unfortunately too often the case. However plausible the arguments on either side may appear, they are valueless in a fair appraisal if they do not recognize that they must appeal to the other party as just and equitable. The company should not place inflated values on an antiquated or inefficient plant, or upon present or prospective earnings, often unduly padded, or upon the fact that it is in possession of the field. On the other hand, the city should not take undue advantage of the fact that it can compel the sale of the plant and that it controls the rates for service, and even the franchise grant itself. Should either side take what appears to be an unreasonable position, the other party would be justified in protecting itself by all legitimate means at its command.

Is it possible for such a value to be fair and reasonable to one party and not to the other? The author believes not. The company may feel that it deserves a greater award, but if the figure named is the maximum which the city is warranted in paying as a sound business proposition, then no higher award is justifiable. On the other hand, the city may feel that it has not received tangible value, or that some features are over-estimated. But if the amount represents definite values, whether "physical," "going" or "franchise," on which the city is in a position to conduct a self-supporting enterprise, then it is fair also to the city. The fair value is inherent in the system itself, and is independent of ownership.

To this, one exception may be noted. Sometimes the law requires the city to set aside a sinking fund of sufficient amount to liquidate the bonds issued to pay for the plant, in a definite period, which period may be less than the life of the plant. A private company need only set aside such a fund as will exactly offset depreciation. In such cases the city's sinking fund and the corresponding annual operating expense must be larger than in the case of a private company. In a recent case which came under the author's observation the actual depreciation was only 1.5 per cent. per year, while to repay the bonds in the required period of twenty years would have called for an annual sinking fund of 3.72 per cent., the rate of compound interest being 3 per cent. in both cases. In such a case the fair value of the plant to the city would be less than the fair value to the company, other considerations being identical. This, however, would just about offset the lower rate at which the city can borrow money.

It is possible that the value of a plant at the time of appraisal may actually be greater than its original cost:

1. There may have been a material advance in the cost of such construction, so that it would cost more to reproduce it.

2. It may be earning legitimate profits at reasonable rates, with the right to continue such earnings.

3. It may have demonstrated its exact and entire suitability to the work for which it was intended, in capacity, strength, power, efficiency and reliability. All doubtful and uncertain questions have been solved. Under such conditions it is certainly worth more than can be measured by the mere cost of a new and untried system.

On the other hand, its value may decrease in many ways:

1. By normal depreciation, wear and tear, or decay of parts, so that they are in need of reconstruction or renewal.

2. By reduced cost of reproduction.

3. By poor design, resulting in demonstrated unsuitability for the work.

(*a.*) The pumping engines, for instance, may be too large or too small. They may not be powerful enough, or there may not be sufficient strength to safely work against the necessary pressures.

(*b.*) Inefficiencies may have developed, resulting in large fuel costs, repairs and maintenance expense, or leakages. The units may not be of suitable modern design.

(*c.*) Excessive wear and tear may have occurred, indicating short life.

(*d.*) There may have developed a lack of reliability, the units being subject to interruptions of service, breakdowns, etc.

4. While the plant may have originally been well adapted to its work, it may become more and more unsuitable as years pass, owing to increased demand or other changed conditions.

5. The plant may deteriorate in value, although of excellent design and construction, as a result of external conditions, which may limit the patronage and reduce the net income.

(*a.*) In water works the supply may be poor in quality, or insufficient in quantity, or both. It may become more and more polluted, or the river may leave the pumping station, as the Missouri river has a way of doing.

(*b.*) The company may be unpopular, due to poor management in either the business or mechanical departments, or for other reasons.

(*c.*) There may be uncertainty as to the future. The franchise and city contracts may expire, and there may be a possibility of rates being lowered.

(*d.*) The existing rates may not be those best adapted to secure the highest net revenue. They may be either too high or too low.

Such valuations may be made in many different ways, those most customary being:

1. Value based upon the original cost of the plant as it exists at the time of appraisal, omitting worn-out or replaced material. To the actual cost of material and labor there should always be added a reasonable sum for necessary general expense, such as administration, legal matters, engineering, superintendence, tests, insurance, use of plant and tools and interest on the money invested up to the beginning of service. Sometimes it is proper to include a contractor's profit. It should be re-

membered that the plant was not built all at once, but piecemeal. Allowance should be made for whatever effect this may have had upon cost.

2. Original cost as above, and in addition the cost of all discarded or changed units. Such a valuation has been advocated on the ground that the sellers are entitled to be reimbursed for all moneys they have put into the enterprise, the claim being that such expenditures for replacement and renewal are necessary and incident to the business.

3. Original cost based on either of the above plans, and, in addition, interest on the investment until the plant becomes self-sustaining. In some cases it has even been argued that interest should be included over the entire period up to the date of appraisal. Water plants are always built more for future than for present needs, and the cost of carrying them until needed may be a reasonable element of value.

4. Original cost computed by either of the above methods, and, in addition, such unavoidable losses as were sustained in the legitimate operation and maintenance of the plant during its earlier years. Private parties do not hesitate to conduct an enterprise at a loss for a few years, when it seems reasonably certain that they will, in the end, have built up a profitable business. Such losses are usually charged up as one item of the cost of establishing the business and become a part of the invested capital. It may be argued that had not the owners bravely footed the losses in the earlier years the plant would never have persisted so as to have reached a profitable condition. Furthermore, had the purchasers themselves undertaken the business at the time the owners did, they would have had to go through a similar unprofitable period. It would seem unfair to take over the plant just when it has reached a satisfactory financial condition without reimbursement for the earlier losses, particularly when the legitimate profit is growing and would soon have wiped out these losses. This, as shown later, approaches the "going" value.

5. From the original cost, determined in any of the above ways, deduct the depreciation the plant has suffered up to the date of appraisal. This method is an attempt to arrive at the actual physical value of the plant.

6. Original cost less depreciation, plus what is known as the "going" value. This latter is of comparatively recent development, but, having much to commend it, now has the sanction of many high authorities. It is the value such a plant

has, over and above its physical value, due to the fact that it is not a bare and idle system, but it is in actual operation, doing business with large numbers of connected customers. It is something like the "good will" of a business, but is even more tangible, as the customers have expended money preparing to use the service and are not likely to discontinue it. Water is a necessity, and in many cases a satisfactory supply cannot be had except from the company. Time, money and intelligent effort have been spent in educating the people up to an appreciation of the many benefits of the use of water under pressure,— its convenience, saving of labor and healthfulness. In many cases solicitors have been employed, connections made free and water supplied without charge for limited periods, all of which expense is believed to be justified by the prospective income. This may continue legitimately long after the system is on a self-supporting basis. Such a plant is unquestionably worth more than a plant of equal physical value, but without connections or business, which it would have to build up by the usual slow process. The "going" value is independent of the franchise value, and may exist where the franchise has expired. It is extremely difficult to place a definite figure upon this value. Some writers have suggested elaborate methods, to which they have evidently given much study, but they involve so many assumptions on which equally able appraisers might honestly differ as to be of doubtful value. It seems to the author that a simpler and less speculative method which has been proposed answers the purpose much better. What did it actually cost the original owner to bring the plant to a self-supporting basis? Is not this represented by the losses of the earlier years of operation? This appears to be an additional argument for method No. 4. It must not be forgotten, however, that the courts have refused to allow anything for "good will" considered on its own basis, where the business is exclusive.

In any valuation which excludes consideration of net earnings it would seem that the appraiser is limited to the cost or value of the plant itself as it stands at the time of proposed transfer. "Going" value, should, therefore, only be considered in so far as it has affected the total cost. Whatever time or money the owners have spent legitimately in building up the business, or in early losses, may, in the author's judgment, fairly be allowed them as "going" value. But where the increase has resulted more from the natural growth of the community than from any efforts or expenditure on the company's

part, the allowance should be small. This is particularly applicable where the appraisal is to serve as a basis for rate making.

7. The estimated cost of reproducing the plant at the date of appraisal. This is manifestly the fairest method, as it bases the transaction upon existing conditions, and it is now the one most generally followed. There is a distinction between cost and value, and the latter is what we are usually after. It is often impossible to ascertain the original cost, but it is not unusually difficult to get at the market prices on material and labor at the time of the appraisal. This rule, however, is subject to exceptions, as when such costs are temporarily abnormal, as, for instance, when prices happen to be soaring, or unduly depressed, or where, for example, the patterns of a particular pumping engine may have been destroyed, and the cost of replacing them would come in.

8. The cost of reproduction, less depreciation, as before.

9. The cost of reproduction, less depreciation, plus "going" value.

10. The "franchise" value, based upon the earning power of the system. This, of course, presupposes that there is a legal franchise, and that it has a considerable period still to run, and that its wording permits the consideration of this feature. In such cases there must be no trouble as to rates, no prospect that they may be reduced. The plant must be adequate to maintain the service. If not, there should be deducted a sum sufficient to bring the plant up to good working condition. There must be no trouble with the water supply, either as to quality or quantity. Such values are usually reached by computing the present value of future net earnings during the unexpired portion of the franchise. Great care must be taken to place the gross income on a conservative basis, keeping in mind the possibility of rate reductions. The operating expenses must be looked into with equal care. They must include not only the ordinary items of labor, fuel, oil, repairs, and maintenance but also administration and office expense, taxes, insurance, interest on the investment, and an annual and uniform charge to sinking fund sufficient in amount to renew all wearing parts as it becomes necessary.

As to the propriety of placing a value on earning power, it would seem sufficient to say that when a company is in the enjoyment of a profitable business, it is reasonable to suppose that a fair amount of brains and good business management have

been put into the enterprise, to all of which the city succeeds. Certainly if the opposite is the case, if there are no profits, but, on the contrary, continued deficits, no purchaser would pay even the physical value of the plant. A city has undoubtedly the right to grant a franchise for a public service for a limited period, and then to take back to itself that service. If that intention is clearly stated in the franchise it would seem that as the owners have had all that their contract entitled them to, they should receive merely the physical value of the plant, plus its "going" value. On the other hand, it would seem equally clear that the ability of a plant to earn legitimate profits is a proper element of its value when its consideration is not expressly prohibited.

11. Scrap or salvage value. This is rarely used, as it seldom happens that a plant goes completely out of business. Occasionally radical alterations are necessary, due to change in the source of supply, location of reservoir or pump house, or to growth of the city in an unexpected direction. Single units, such as boilers, pumping engines or filters, often wear out and are abandoned, but rarely or never an entire plant.

Such valuations are often complicated by the conditions laid down in the franchise to govern the work. Where these directions are clear they should be followed to the letter. Often, however, they have been loosely drawn and have resulted in endless litigation. Even where the meaning is reasonably clear to the layman, skilled lawyers, retained by the one side or the other, have succeeded in casting more or less ambiguity upon it.

Evidently there is wide choice as to which of these methods shall be used in any given case. If the principals in interest can agree as to the method of valuation, they should give explicit instructions accordingly. This will save a vast amount of trouble. If, as more often happens, no such instructions are to be had, then the engineer must use his best judgment and select that method which appeals to him as being the fairest. The considerations governing his selection of method should be sound and he should approach the matter without bias. His reasoning should be such as will be admitted to be fair by both parties. Particularly should this be the case where he is the arbitrator, or a member of a board of arbitration. He should never forget the judicial position he occupies. If, however, he is retained by either party to the controversy to appear as an expert before such a board, or in court, then it is his duty to see

that all the evidence, data and argument which legitimately and properly affect his client's case are fully and clearly presented. In those cases where there is room for honest difference of opinion,— and there are many such,— he is justified, in all fairness and good faith, in seeing that the point of view which most favorably affects his client's interests is properly and clearly set forth.

A brief consideration of the eleven methods above mentioned may assist in making a proper selection.

Evidently the first four are based upon the idea of returning to the company the entire amount of money it has invested, irrespective of whether the value is still there, and without regard to whether the money was wisely expended. No consideration is given to the present condition of the plant, its efficiency, or whether it is self-supporting or not. Such cases are rare and would never seem to be proper except where the "going" value justified a material addition to the physical value, or where the franchise permitted consideration of value based on earnings.

Method 5 is justifiable as representing an effort to reach existing values. The proper computation of "depreciation" is, however, a matter of some difficulty, as will be seen later.

Method 6 is a still nearer approach, as are also 7, 8 and 9. The latter represents the author's ideas more fully than any of the others.

In those cases, however, where it is proper to consider franchise or earning value, then Method 10 should be given due study in connection with the physical and "going" values, as already explained.

Plan 11 is of such rare application as to need no further consideration.

Methods 9 and 10 appearing to be the preferable ones, they will be considered in further detail.

Clearly the two are interdependent. The plant may be of excellent design and in first-class condition, but if operated at a financial loss its value is correspondingly reduced. On the other hand, the net earnings may justify a value above that of the physical property alone. The determination of the cost of reproduction usually presents no serious difficulties after a complete inventory has been prepared and verified. It then remains to assume a life period, or term of amortization, for each unit of the plant, and to compute the depreciation to date.

As will be seen later, there is some uncertainty as to the

average useful life of various portions of the plant. The inspection which accompanies the making or checking of the inventory, however, will usually throw light on this question. If any unit shows signs of decrepitude, or is of limited usefulness for any reason, it has already depreciated largely. This, with a study of the views of experienced authorities, will generally provide a basis for sound action in the premises. Some data on the life and depreciation of various features of water and other plants have been collected by the author from various sources and are tabulated later herein.

Depreciation should, of course, be figured sufficiently high to cover not only the wear and tear, lowered usefulness and obsoleteness of design, but also the possibility of accidents and of lower market prices for apparatus, material and labor at a later date of appraisal.

Two methods of determining depreciation are in common use. Under the first, known as the straight line method, after the unit under consideration has been examined and its probable life, or term of amortization, fixed, it is assumed that its value decreases uniformly during that period. If, for instance, the assumed life is twenty years, and ten have elapsed, then its value is 50 per cent. of its first cost, or the cost of reproducing it at the time of appraisal. This is the simplest, most direct and most natural method, and is the one which at first glance appeals to most engineers. The author — in common, he believes, with many others — has employed it almost exclusively heretofore. It takes no account of sinking fund or other bookkeeping methods.

A second method, and one which now has the sanction of many authorities, assumes that a fixed amount has been set aside each year at compound interest, and that this sum, and the accrued interest, form a sinking fund which, at the end of the assumed life of the unit, will be sufficient in amount for its renewal. The value at any intermediate date is the first cost, or cost of reproduction, less the gross amount of the sinking fund at that date. In the event of sale it is assumed that the new owner will continue the plan; in which event it will "pay out" for him exactly as it would have done for the original owner.

The essential difference between these two plans is that under the first the drop in value is the same every year, while under the second it is light at first, gradually increasing until towards the end, when it rises more rapidly. The loss to the original owner under Plan 2 is small, the later purchaser having

to bear the increasing depreciation losses. To what extent is this plan justified by the facts? The difference between the two methods is not great for units of short life, but it is quite marked on those portions of long duration, such as the underground mains.

Both plans, however, assume that the loss in value follows a uniform law, the first dropping by equal steps each year, and the second by gradually increasing amounts. Both assumptions are in most cases at variance with the truth. Let us consider in somewhat further detail a few of the items which enter into an ordinary water-works valuation:

Real Estate. — This is not usually subject to great fluctuations. In the smaller conservative towns values remain nearly constant. If in a progressive community, they tend to increase. In the larger growing cities there would usually be a reasonably sure and steady advance. This, of course, leaves out of consideration real estate booms, collapses, etc., which, when they occur, must be given whatever value the situation warrants.

Buildings. — The ordinary well-built structure has a long life, and its deterioration is slow and reasonably constant unless affected by external circumstances. Power plant buildings deteriorate to some extent, however, from the effects of heat, steam and moisture from boilers and pipe work, and the vibrations of machinery. More often, however, their usefulness is impaired, and often ended, by the demand for greater capacity of machinery, or newer types, which require buildings larger in size and different in character and arrangement. In addition to examining into its physical condition, therefore, it is necessary to estimate the probable future usefulness of the building and its adaptability for such future changes as may be necessary. The life of good brick buildings is variously placed at from twenty-five to one hundred years, averaging forty to fifty; ordinary frame buildings, twenty years.

Boilers. — These being subject to severe usage are probably the shortest lived portion of any plant, depending upon the service, water, fuel and care they receive. The output of the average boiler plant, however, is fairly uniform, and its loss of value equally so. After a boiler has become too worn for regular service it still has a small value for occasional use as a reserve unit, or for helping out for short periods at the peak of the load in electric plants, or at times of fire service in water works. Authorities have placed their life at from ten to twenty-five years. Mr. J. W. Alvord * collected reliable data from thirty-

* Proceedings American Water Works Association, 1903.

two boilers whose useful life ranged from six to twenty-three years, averaging fifteen.

Pumping Engines. — These have a value subject to many fluctuations. An engine which has proven itself well adapted for the intended work in capacity, power, strength, fuel, efficiency, smallness of repairs, reliability, etc., may actually be said to have increased in value when these characteristics have been fully demonstrated. It has evidently been wisely chosen, and when the attendants have fully familiarized themselves with all its characteristics, there is no longer anything experimental or uncertain about it. Assuming ordinary renewals and repairs as needed, its value for the work in hand may not drop materially for many years, as the wearing parts are easily renewed and at small expense. This condition continues until the time arrives when it is no longer large enough for the work, and an additional or larger engine must be installed. It may continue to run, however, at a lower value, doing part of the work, for some years to come, when still further additions may have to be made to the plant. These additions will probably be larger in capacity, and of higher efficiency, making it less and less desirable to run the original unit. A time will come, therefore, when it no longer pays to run this engine in regular service. After this it still has some value as a reserve unit and for helping out at times of maximum or fire service. To every engine, of course, there comes a time when it no longer pays to repair it, as, for instance, when the steam cylinders can no longer be bored out, valve seats trued up, or when the room it occupies is needed for other purposes. There is also the possibility, remote, of course, with the best types, of accident, which may seriously damage the engine, possibly beyond repair. Both engines and boilers sometimes have a considerable scrap value when no longer fit for use. Their life has been placed by good authorities at from ten to thirty-three years. Mr. Alvord's records of fifty engines ran from three to thirty-six years, averaging 21.3.

Cast-Iron Pipe. — There is wide variation among good authorities as to the average life of well-coated cast-iron pipe. Some assume it at one hundred years under favorable conditions, but there is little definite ground for such a figure. Instances are known where pipes of this age have been examined and found in good condition. In many cases, however, it has been found to be more brittle than when installed. Some waters cause a tendency to corrosion internally, and most waters make a deposit of tubercles which, even if they do not eat through the

coating, in time materially cut down the pipe's capacity. This is more noticeable with soft or surface waters than with hard waters. Furthermore, there are many soils, and many waters in the soils, which cause external decay. There is also the possibility that the demand for water for ordinary and fire service in some sections of the city may increase beyond the capacity of the existing mains. In most cases, however, it is not necessary to abandon or even change the pipe on a particular street on this account. A new line of larger capacity may be laid on the same or on a parallel street, thus bringing up the pressure throughout the entire district. This line, in connection with the existing lines, gives the improved service without abandoning the old lines, these continuing in use, doing their share of the work. In some cases considerations of first cost have compelled the installation of small mains, 3 or 4 in.; also of even smaller wrought-iron lines. These are of low capacity, subject to rapid choking up, and are practically valueless for fire protection, while the wrought-iron lines are usually short lived. For these reasons they must usually be replaced at an early date, and some authorities refuse to allow any value for them. This, however, is an extreme view. Each case should be studied on its merits, and whatever value actually remains in such lines should be awarded. In most cases depreciation results from internal incrustations cutting down the capacity of the mains, particularly for fire service. This would seem to indicate the necessity of frequent severe flushings or cleaning by scrapers or other mechanical means wherever possible. It is evidently of great importance that in every case the pipe be carefully inspected, both externally and internally. The maximum life, in good soil and with waters which form no internal incrustations, if such exist, may be said to be unknown. Knowing the effect of soils and waters, of increasing brittleness, and of higher pressures and shock, limits have been placed all the way from twenty to one hundred years, with perhaps the best practice at about seventy-five for average favorable conditions. This figure, of course, should be decreased or increased should local examination necessitate. As both the internal deposits and the demand for water are small during the earlier years, the depreciation in value is low, but it increases in the later years with growing incrustation, demand and brittleness.

Standpipes. — These may be said to increase somewhat in value at the start if they prove well adapted to their work. Their principal value in the smaller systems is for storage to

avoid night pumping. They also permit shutting down the pumps temporarily at any time, and provide an emergency supply over and above what the pumps can furnish, when needed. A further important function is the regulating of the fluctuations of demand without shock on either the pumps or the distribution system. Evidently standpipes are subject to deterioration under the ordinary effects of corrosion, ice and wear and tear generally, and their value is dependent upon the sufficiency of their dimensions and design for meeting the desired conditions satisfactorily for a term of years. There is, of course, a drop in their value when the consumption reaches such a point as to demand night pumping. Examinations of a number of standpipes by the author show greater depreciation internally than externally, assuming the outside to have been kept well painted. The bottom, which is usually found covered with sediment, is generally well preserved. Above this the same tubercles are found as in the cast-iron mains, with the important difference that under each there is a large pit where the wrought metal has been eaten away. Large numbers of rivet heads are corroded away on the upper portions of their heads, where more or less sediment has collected. These defects decrease as the height increases, ending at about the low-water line. Here there is a marked deterioration of rivet heads, but above this point the tank is usually found in good condition. Authorities place the life of ordinary wrought-iron standpipes at from twenty-five to forty years.

Reservoirs and Dams. — Assuming these to be well designed and well built, their life may be considered indefinite. Those reservoirs, however, built for the smaller cities, with earth dams and walls, intended for impounding purposes, may lose value by the effect of wave wash and sedimentation, the burrowing of animals, as well as gradually becoming too small for settling and storage. The effects of ice and freezing are also detrimental even to masonry, as are also the ordinary wear and tear of filling, emptying and cleaning, removal of sediment and the alternate exposure to air and water.

Having thus briefly outlined the progress of depreciation as it actually occurs, it remains to be seen which, if either, of the above rules offers the better method of computing present value.

Let us consider two divisions of the plant, the pumping engines and the cast-iron mains. These, in the author's judgment, fairly represent the range of the characteristic depreciations

which occur throughout a water plant. It would seem that a rule which will apply to these may safely be used with reference to the entire plant.

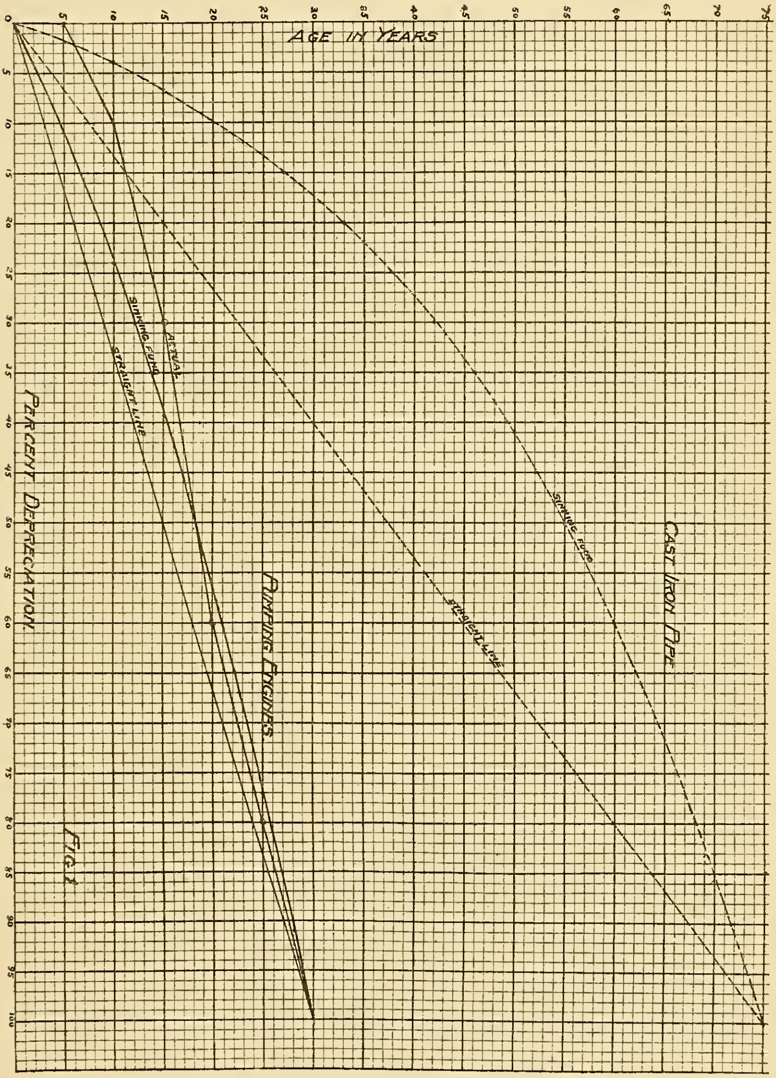


FIG. 1.

On Fig. 1, I have plotted the values of an ordinary pumping engine of an assumed life of thirty years, figuring depreciation, first by the straight line method; second by the sinking fund

method; and, third, as it seems to occur in actual practice. The abscissæ represent the percentage of depreciation, and the ordinates the age of the unit.

At zero age, the beginning of the life of the unit, its depreciation is, of course, zero, and when the end of its life has been reached its depreciation is 100 per cent. The proper values at intermediate dates, however, are matters of some complication, as already explained. To use Fig. 1, find the age of the unit in the column of ordinates on the left; then proceed horizontally across the page to an intersection with the particular curve in use; then continue at right angles to the base line, at which point the percentage of value which the unit has lost up to that date will be found. If the straight line method is followed its value at any intermediate date is represented directly by the proportion of the useful life which has yet to elapse. In using the sinking fund method it is necessary to ascertain what sum has accumulated in that fund at the date of appraisal. This deducted from the cost of reproduction gives the value.

This involves a consideration of the characteristics of the sinking fund. It assumes that at the inception of the plant a life period for each unit has been assumed and the annual payment computed, which, with compound interest, will, at the expiration of the period selected, provide a fund sufficient for the renewal of the unit. If this plan has been faithfully adhered to there is at any intermediate date an amount in hand which, if deducted from the original value (or cost of reproduction), will fairly represent the present value. This money is supposed to be safely invested so as to earn interest. Or it may be returned to the stockholders and the plant value as an asset charged off to correspond, or the amount may be used for the retirement of the bonded indebtedness, as is often done.

As a matter of fact, such funds are rarely if ever found in practice. This, however, is immaterial to the appraiser, who uses the method simply as a fair means of reaching present value. It is, of course, simply a question of computing compound interest. The result is a geometrical series, the actual computation of which in any given instance is tedious. Fortunately tables have been prepared giving these values for various periods of years, and at different interest rates, and from these curves have been plotted which render the computations easy and simple. The regular curve in Fig. 1, represents such a sinking fund compounded annually at 3 per cent., as such funds necessarily bear a low rate of interest. If we follow the sinking fund plan we

find that at the age of five years the engine would have depreciated about 6.5 per cent.; at ten years, about 25 per cent.; at fifteen years, about 38 per cent.; at twenty years about 55 per cent.; and so on.

What has the depreciation actually been? Let us assume an ordinary pumping engine of good design and construction receiving intelligent care, ordinary maintenance and repairs being well kept up. Such an engine in the average plant would probably serve its intended purpose for the first five years with no depreciation whatever. In fact, as explained above, it might even be claimed to have advanced somewhat in value. Assuming a growing consumption of water, it might be assumed that after five years it would begin to be necessary to run this pump at excessive speeds, or to pump longer hours, in order to avoid the employment of a night pumping crew. This reduced efficiency and increased labor will cause a drop in value which we assume has reached 10 per cent. at the end of 10 years. When the demand finally exceeds a quantity which can be pumped with a single day crew, even under forced conditions, there is a further drop in value. It then becomes necessary to put on a night crew, which handles the service satisfactorily up to the fifteenth year, the value, however, having dropped a total of 30 per cent. As the demand continues to increase, excessive speeds and continuous operation day and night become necessary, at a correspondingly reduced efficiency and increased cost of repairs, which bring the depreciation at the end of twenty years to 60 per cent. At this time it becomes necessary to add another engine, so that the original pump is used only in connection with it at times of maximum demand, or for occasional reserve use. Running only part of the time, and at reduced efficiency, its value, we may say, declines to 80 per cent. at the end of the twenty-fifth year. After this, the wear and tear of essential parts, such as cylinders, valve seats, etc., beyond reasonable repair, together with the ordinary usage to which it may reasonably be expected to be subjected, such as occasional neglect and overwork, have practically ended the pump's value for regular service. It is, however, kept in position and occasionally operated for a further period of five years as a reserve. By this time it has practically worn itself out and the space is needed for other and more modern units of larger capacity. If the unit can safely be assumed to still have a scrap value greater than its cost of removal, such value should be deducted from the cost of reproduction, and the depreciation figured on the remaining

value. It is doubtful, however, whether such possible scrap value should be given much weight, as it is impossible to predict the actual condition of the pump, and its antiquated design would probably limit the chances of advantageous sale.

In Fig. 1, the line marked "actual" is intended to represent this story of depreciation. It will be noticed that at all times the pump's value is above that indicated by the straight line method, during its earlier life materially so. While the sinking fund curve does not accurately represent its value, it approximates it much more nearly than the straight line.

In Fig. 1, a similar comparison between the straight line and sinking fund methods as applied to cast-iron pipe of an assumed life of seventy-five years is also shown. The marked difference between these methods when applied over a long period of years is here emphasized. For instance, at twenty years of age, the pipe, according to the sinking fund curve, has depreciated but 10 per cent.; at thirty-seven and a half years, half its life, only 25 per cent.

It will readily be seen, therefore, that the method to be selected is of great importance when considering the long-lived features of the plant.

How does the depreciation of a system of cast-iron mains actually occur? In its earlier years it serves its purpose efficiently, the consumption being small and the pipe practically free from incrustation. As the years go by, the pumpage increases, the friction losses grow, and increasing incrustation reduces the capacity of the mains and adds still further to the friction head. Furthermore, increased brittleness is found, and there are breakages here and there. No very definite values, however, can be figured for these losses in value, but it is evident that in a general way they are small during the earlier years, and increase more and more rapidly towards the end, evidently following reasonably close to the sinking fund curve.

Similar analyses might be applied to the other features of the plant, the building, boilers, reservoirs, standpipes, valves, hydrants, etc., but in practically every case it will be found that the depreciation is low at first, increasing later, and is, therefore, better represented by the sinking fund curve than the straight line.

Having then the cost of reproduction of each feature of the plant, its assumed life, and a sinking fund curve to correspond, we may at once arrive at a value for that unit. The sum of these is the present value of the entire physical plant. Care must be

taken, however, to insure that such computed value is in harmony with the physical appearance, performance and usefulness of the unit as noted by careful inspection at the time of appraisal.

As indicating how such computations work out, the following recent figures are given: A water system, built in 1888 at a cost of $61 443, could be duplicated, including worn-out parts, in 1907, for $63 893. The present value of the remaining physical property is $38 478. The depreciation in nineteen years has, therefore, been $22 965, or 37.3 per cent. of the original cost. This covers not only the actual physical depreciation, including the abandonment of certain worn-out parts, but allows for the present higher cost of duplication. This amount would have been available at the end of the nineteen years if the sum of $914.24 had been set aside each year as a sinking fund, and compounded annually at 3 per cent. interest. This sum, which is 1.488 per cent. of the original cost, should, of course, have been considered as one of the regular and legitimate items of operating expense. Had this sinking fund been continued it would have wiped out the entire original cost in 18.35 years more, a total of 37.35 years, which may be taken as the average life of the plant as a whole. The depreciation included in this case the abandonment of two settling basins and one filter and filter house. As the worn-out parts had been fully cared for, only $681.90 of the original sinking fund payment then remained in force.

During the nineteen years in question, betterments and extensions were made, bringing the original cost up to $81 363, and the cost of duplication to $87 965. The appraised value of the whole in 1907 is $59 691. Detailed consideration of each of the units of the system showed that the total annual charge to sinking fund to cover present depreciation should now be $982.68, assuming that the entire amount which has previously accrued to the credit of sinking fund is available and is continued at compound interest. If, however, a fresh start is made, on the basis of the reduced valuation, then the annual payment to sinking fund to make good that value (not the original cost or cost of duplication) must be increased sufficiently to make up for the missing interest of the earlier fund, now charged off. In the case referred to, this payment became $1 583.48 per annum, or 2.86 per cent. on the present value, which amount would repay that value in 25.7 years more.

The above figures bring out what have been claimed to be the weak points of the sinking fund plan. If rigidly carried

out it will do all that is claimed for it, in justifying a higher value for the plant in its earlier years and in reducing the annual cost of operation as a result of the low payments to sinking fund. But when no such fund exists,— as is nearly always the case,— complications seem to arise. After the purchaser has taken over the plant at the figure thus arrived at, he must, in order to carry out the scheme, set aside an additional amount, equal to the previously accrued sinking fund, and continue it at compound interest, besides keeping up the original payments to sinking fund. If he does not do this, and he rarely or never does, then he must establish a new and increased annual sinking fund. Not only has he paid what appears to be high price for the plant, but he must take care of the entire balance of depreciation in the few remaining years of its life. It has been questioned, therefore, whether a wholly imaginary plan, which imposes such obligations upon the purchaser, is altogether fair.

To this it may be answered that the mere fact that the plan involves bookkeeping methods which may not actually have been followed, should not be an objection so long as the results are just and fair to both parties, and in reasonably close harmony with the actual depreciation. The purchaser should expect to put himself in the place of the original owner, assuming all his responsibilities and obligations, one of the most reasonable and necessary of which is the maintenance of such a sinking fund. Whether such a fund is actually in hand or not, the owner does his full duty when he allows its computed amount to be deducted from the cost of the plant. Should the purchaser be unable or unwilling to replace this sinking fund so as to continue and carry out the scheme, he must accept the consequences of such action by making provision for an increased future sinking fund.

Having thus fixed the physical value of the plant, it is in order to inquire whether good reasons exist why this value should be either increased or decreased. Are any of the other considerations hereinbefore referred to applicable to the case under consideration, particularly the " going " and " franchise " values?

As a preliminary to further discussion, we may pass at once to the consideration of earnings. If the plant is not earning a profit, or has reasonably certain prospects of doing so in the immediate future, it is unnecessary to consider either the " going " or " franchise " value. In such cases, which are by no means uncommon in the smaller cities where there is often little

or no growth, the company is usually more anxious to sell than the city is to buy. Having been a losing proposition, the owners are anxious to get the plant off of their hands. The city, on the other hand, being usually familiar with the situation, is in no hurry to take over the plant, and will only do so on a valuation commensurate with the financial returns which may be expected, due allowance, of course, being made for such public uses of water as for fire hydrants, street sprinkling, flushing of sewers and gutters, public buildings, fountains, etc. Under such circumstances, in order to have consideration at all, it may be necessary that the price fixed be equal to or even lower than the fair physical value. This, of course, is unfortunate for the owners, but there seems to be no fair remedy. They have simply gone into an unprofitable venture and must meet their losses, just as they would have been entitled to absorb the profits had the opposite been the case. To put it another way, the actual worth of the service to the people fixes a maximum beyond which no estimate of value, however logical, can go.

It has been argued that "going" value may exist even when a plant is losing money. It is of course true that a plant with some business is worth more than one with little or none. But to be worth even its physical value it must be earning enough to meet all legitimate operating expense, together with interest on that value, and a sinking fund for depreciation; or such earnings must be reasonably certain in the not too distant future. If, however, we start with a value based on earnings (which in the case of a losing plant would be below the physical value), then something might be added for "going" value.

Assuming, however, that there is a clean and legitimate profit, present or immediately prospective, it may be in order to consider both the "going" and "franchise" values.

Referring back to Method No. 6, of valuation, with its further reference to Method 4, the author would base "going" value upon the losses sustained in the legitimate operation and maintenance of the plant during its earlier years, up to the time it became self-supporting. Often these losses are shown by the company's books, which, however, should be scrutinized carefully to make sure that they have been correctly kept. Even when the books do not give these figures, the date when the plant ceased to lose money can usually be fixed, and it would not ordinarily be difficult to make a reasonably close estimate of the probable losses previous to that time. Any amounts which can be shown to have been spent directly for

building up the business should also be added. In the author's judgment such a computation does not involve anything like as many difficulties as other methods which have been proposed.

Should worn-out and replaced material be included in such losses? Where such renewals come as a result of natural wear and tear, they are supposed to be covered by the annual charge to depreciation or sinking fund. But where it results from poor design or construction, or unsuitable material, and is in no way necessarily incident to the conduct of such a business, it should be excluded.

Two cases of such computations, however, appear abnormal:

1. Local conditions may lead to an immediate and extensive demand for water, the company making the connections as fast as they can be handled, very soon reaching a large and profitable consumption. In such cases the cost of getting to an earning basis would be a minimum, whereas the value of such business would appear to be a maximum.

2. Take also the opposite case, where the town is slow and conservative, and where there may be good cisterns and wells which the people are in no hurry to abandon. In this case it may be many years before a self-sustaining business is established, and many more before the profits are of any magnitude. In such cases the earlier losses would be a maximum, and the business when secured would be of small value.

In the first case, it may be said that the business thus favorably secured was due less to special efforts on the part of the company than to the favorable local situation. Having resulted from the efforts and needs of the people themselves, and the growth and development of the community, the principal value comes from, and should remain in, the city itself. This is fair even though the presence of an efficient water system may have contributed to that growth.

The second case is again a question of net earnings. If these do not warrant an addition to the physical value, then the city could not afford to pay for same, nor would it be proper for an appraiser to make such an award. If, however, these earnings have finally become substantial, and there is reasonable prospect that they will continue to advance, the author sees no objection to a material award for "going" value, equaling possibly the full amount of the losses which have been sustained. The owners have bravely fought what was for a long time a losing battle, but having finally triumphed, they should not be barred from an opportunity to recoup themselves without due reward.

Suppose that after the plant has become self-supporting the customers continue to increase, and that money is expended in getting them as before. Also that at the time of appraisal the connected business is many times greater than originally sufficed to merely pay expenses. Should not this justify an increased " going " value?

It would seem so, and this value might be assumed to bear the same ratio to the " going " value at the time the plant first met expenses that the present number of connections bears to the number then.

On the other hand, something may be said against such increased value. The system now being self-supporting, it might be argued that the increased business has really cost the company nothing. If money was still being spent for this purpose, the owners, having no ground to assume that it would ever be repaid, must have felt satisfied that it would be fully returned in profits during the unexpired portion of the franchise. In most cases the business has increased as a result of the development and growth of the community, for which the people deserve more credit than the management. Furthermore, such a value verges dangerously close to one based on earnings, which may be forbidden. To which it may be added that in such cases the greater profits have long since paid off the earlier losses, which form our basis of " going " value.

We come now to the " franchise " value, or value based on earnings. This value, of course, depends upon three contingencies:

1. That the wording of the franchise permits its consideration.

2. That there is a net legitimate profit, after due consideration has been given physical and " going " values.

3. That the franchise has still a considerable period to run, during which such earnings may reasonably be expected to continue.

Assuming all these conditions to exist, however, it is fair to add a further value based on earnings. The profits for the preceding years should be looked into very carefully, and all the matters mentioned in Method 10 above should be given due consideration so as to get at a fair basis and average of these earnings. Interest should be computed upon not only the physical, but the " going " value of the plant, if such a value has been fixed. With this data in hand it should be possible to predict with reasonable accuracy the probable earnings for each year of the unexpired portion of the franchise. These should

then be reduced to their present value, figuring a low rate of interest, and the whole added to the sum of the physical and "going" values.

In those states, notably Illinois and California, where the law gives municipalities the right to regulate water rates, conditional only on earning a fair return on the investment, it would seem that no water plant could ever have a "franchise" or "earning" value.

Earlier in this paper (see page 339) there was given a list of considerations which would affect the value of the plant, tending in some cases to increase that value, and in others to lower it. What effect, if any, would these have on the value established as above?

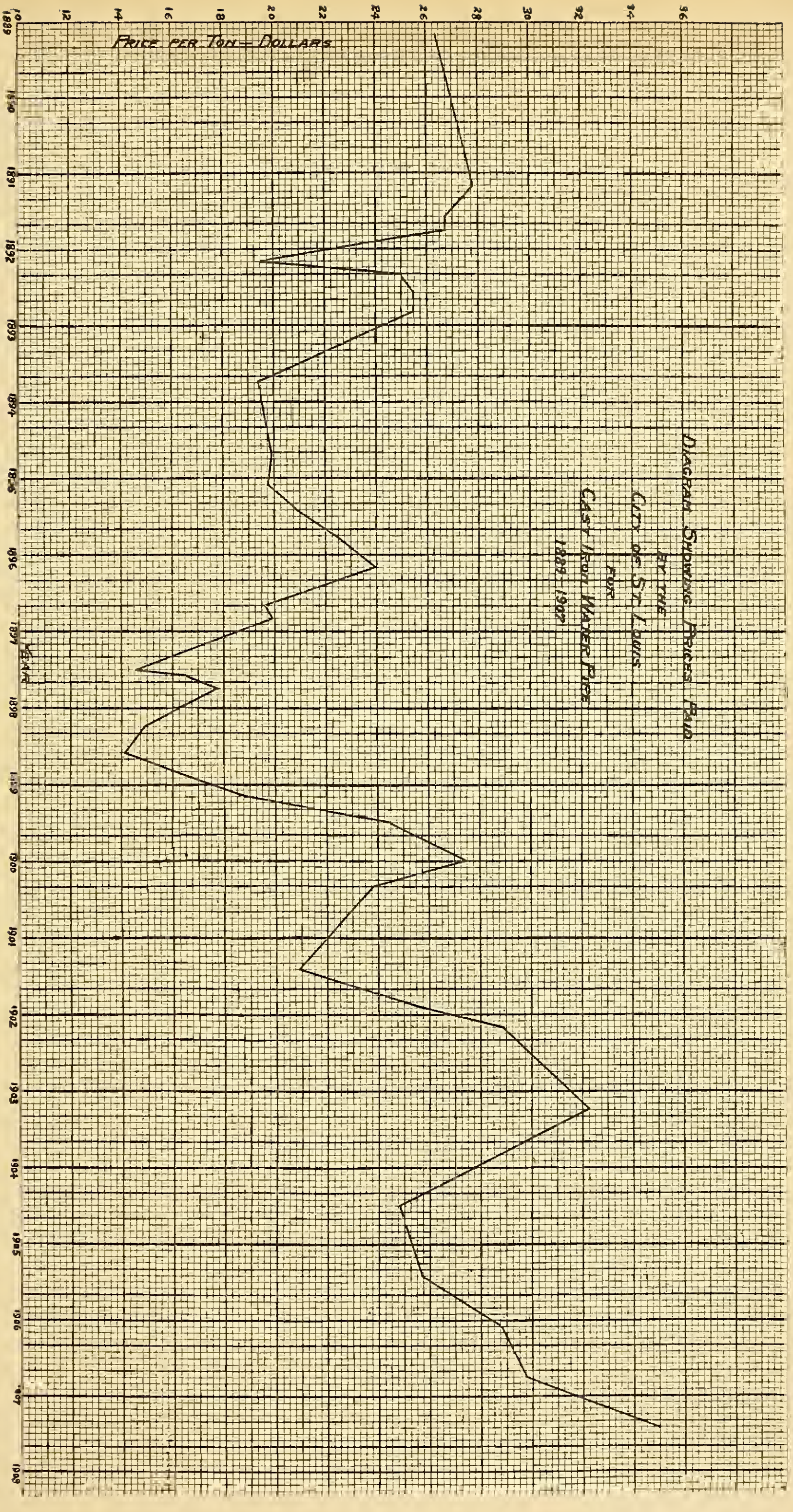
Taking up first those items which might increase the value above the original cost, it is evident that items one and three, covering the advance in cost of construction, and the fortunate suitability of the plant for its work, are fully cared for in the valuation based on cost of reproduction less depreciation. The second item — that resulting from the profits earned — is taken care of by the earning value.

As to the items which might decrease value, it is evident that the first four, namely, wear and tear, reduced cost of reproduction, poor design, and growing unsuitability for the work, are all cared for in the estimated cost of reproduction less depreciation. Item 5 *a*, which concerns the quantity and quality of the water supply, might properly be considered both as affecting the suitability of the plant for its work,— in other words, its physical value, — and also under earnings, as these would undoubtedly be affected by such a consideration. The remaining items, 5 *b*, *c* and *d*, poor management, uncertainty as to the future, and probable rates, all receive due consideration under the value based on earnings. It would seem, therefore, that the method outlined takes care of all possible contingencies.

To these figures there should usually be added the value of tools, material, repair parts and supplies on hand as shown by verified inventory. This should be again verified or revised by the parties themselves at the date of actual transfer.

This latter total is the sum which, in the author's judgment, should be fairly recommended as the proper value of the plant.

In computing original and present costs it is important to know the ruling prices of cast-iron pipe at various dates. Through the courtesy of Mr. W. E. Rolfe, of the Water Department of the city of St. Louis, I have secured the prices paid by that muni-


Price per Ton — Dollars
Diagram Showing Prices Paid
by the
City of St. Louis
for
Cast Iron Water Pipe
1889 1907
Years
10
12
14
16
18
20
22
24
26
28
30
32
34
36
1889
1890
1891
1892
1893
1894
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1896
1897
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1900
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1906
1907
1908

FIG. 2.

cipality for eighteen years back. These are shown in the accompanying table and chart, Fig. 2. The quantities purchased, and the large sizes and weights employed, give such a purchaser a decided advantage over the ordinary buyer. This should not be forgotten when making comparisons.

After all has been said and done, however, it must not be forgotten that such a value is not capable of exact mathematical determination. The best that can be done is to place it within comparatively narrow limits. When it is necessary to fix upon a definite figure, the appraiser must exercise his best judgment as to disputed or hazy points, often arbitrarily it may seem. But when he has done this, fairly, impartially and in good conscience, in the light of all facts and equities as he sees them, he need fear to look no man in the face.

There has been much loose thinking in these matters, for a share of which we engineers are not altogether without blame. Cases are on record of gross errors both ways, where plants have been unloaded on to communities at inflated values, and others where the cities have practically confiscated them. Capital invested in legitimate water-works enterprises is entitled to the same protection and return as in other directions. Such investments should, if possible, be made attractive to capital; they should be safe and sound. Unfortunately this has not been the case for some years. Bonds secured solely on the plant itself, whether municipal or private, are extremely hard to market, and it is becoming more and more difficult to organize private companies to undertake water franchises. It is the hope of the author that this discussion may assist in bringing about a clearer and a fairer understanding of this interesting matter from every standpoint.

Table showing Estimated Life and Depreciation of Apparatus, Machinery, etc., Compiled from Various Sources by William H. Bryan, M.E., St. Louis.

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Material.	Life in Years.	Depreciation. Per ct. per yr. Straight	Sinking Fund.	Authority.	Remarks.
Entire Systems: Electric Light		10		4	Am. Inst. E. E.'s.
,,	12.33	8		4	N. Y. Edison Co.
			3	4	English municipal Engineers.
,,		5		4	Mass. Gas & El. Com.
,,		7.5–10		4	Motions made but not adopted.
,,	12.5, 14			5	
,,	16.66, 20				
		6.4–7.4		6	
Water Works		1.465		1	Los Angeles, Cal., 29.3% in 20 yr.
,,		1.667		2	Kansas City, Mo., 33.3% in 20 yr.
,,		1.1		3	Tuttle, 22% in 20 yr.
,,		.62		*E. R.*, 7–23–'04	Quincy, Ill., 18.7% in 30 yr.
,		2.47		*M. E.*, May, '03	Valparaiso, Ind., 37.1% in 15 yr.
,,		.86	1.58	*E. N.*, 4–23–'03	Mobile, Ala., 12% in 14 yr.
,,	37.35	1.95	1.49	6	Washington, Mo., 37.3% in 19 yr.
,,	40			3	C. Palmer.
,,			1	*E. R.*, 6–1–'01	Court Contra, Costa, Cal.
,,	37		1.50	3	F. C. Coffin.
,,	31		2	3	Haverhill, Mass.
,,		1.99		6	Rich Hill, Mo.
,,		2.21		6	Galena, Kan.
,,		2.91		6	Mt. Carmel, Ill.
Water, Gas and Elec. Light Plants (Average of 52)		2.784		*E. N.*, 5–7–'03	14th An. Rep., U. S. Com. of Labor.
Arc Lamps	8			5	
,, ,,	12–15			6	
Belts	3–4			7	

Material.	Life in Years.	Depreciation. per ct. per yr. Straight	Sinking Fund.	Authority.	Remarks.
Boilers	6–23. Av. 15			8	Average of 32.
,,		5–7		9	
,,	15			15	
,,	20–30			2	
,,	20			10	
,,	10–12.5			7	
,,	14–15			5	
,,	25			11	
,,	30			12	
,,		8		13	
,,	14.3–25			6	
,,		2.5–4		14	
,,		6		16	
,,	25			17	
Bonding, Track		8		13	
,, ,,	10–16			7	
Bridges					
Iron		5		9	
Masonry		1		9	
Trestle		15–20		9	
Buildings					
Brick		2		5	
,,		2		9	
,,	40			15	
,,	25–40			6	
,,		7		14	
,,	60			10	
,,	50–100			7	
,,	25–33–50			5	
,,	30			11	
,,	30			12	
,,		5		13	
,,		3.5		16	
,,	35			17	
Wooden		5		9	
,,		4		14	
,,	15–30			6	
Cables, Feeder	20–35			7	
Cars	15–25			7	
,, Bodies		7		13	
,, Motors	12.5–20			7	
,, Trucks		8		13	
Condensers		7–10		9	
,,	12.5			5	
Conduits		3–5		9	
Converters					
Stationary	15			10	
,,	15–20			7	
,,	12.5			5	
,,	10–12.5			6	
Rotary	10–12.5			7	
Engines					
Steam		4–6		9	
,,	25			10	
,,	15–25			7	
,,		8		13	
,,	20	5		6	
Pumping	20–25–30	5		6	
,,		3–10		9	
,,	15			15	
,,	20–30			2	
,,		4.7		14	
,,	25			10	
,,	10			5	Boiler feeds, etc.
,,	3–36. Av. 21.3			8	Average of 50.
,,	25–30			11	
,,	30			12	
,,		2.5		16	
,,	30			17	

Material.	Life in Years.	Depreciation. per ct. per yr. Straight	Sinking Fund.	Authority.	Remarks.
Engines & Generators					
Belted	10–20			7	
Direct connected	12.5–25			7	
Filters, Water	15–20			6	
Gear Cases		20		13	
Generators	15			6	
"		7–12		9	
"	25			10	
"	10–20			7	
"		3		13	
Hydrants, Fire	25–35			6	
" "		2		1	
" "	40			11	
Insulators					
Pole Line		12		13	
Trolley		7		13	
Meters					
Electric	10			10	
"	10			5	
"	10–12.5			7	
"	10			6	
Water		3		1	
"		2.1		*E. N.*, 4–23–'03	Mobile, Ala.
"	20			11	
"	20			6	
Motors					
Car	12.5–20			7	
Armatures		33		13	
Commutators		33		13	
Controllers		4		13	
Fields		12		13	
Paving,					
Asphalt		7		13	
Brick		7		13	
Cedar Blocks		16		13	
Granite		5		13	
Macadam		6		13	
Pipe					
Cast Iron	50–75			6	
"	68			*E. R.*, 8–28–'97	Los Angeles, Cal.
"		1.25		1	Do., Good Soil.
"		2		1	Do., Poor Soil.
"	20–60			3	R. Hering.
"	25–60			2	
"	70			15	Gas Mains.
"	Over 50			3	Pearsons.
"		1.14		14	
"		1		16	
"	100			8	
"	100			17	
"	80			11	
"	75			12	
Service	10			6	
"		2.5		1	
"		5		16	
Wrought Iron	30			11	Underground.
"	20			12	
"	15–20			6	
"		5		16	
In Plant	15			15	
"	25			10	
"	14–15			5	
"	20–30			6	
"		10		16	
Pole Line	15			6	
" "		12–15		9	

Material.	Life in Years.	Depreciation. Per ct. per yr. Straight	Depreciation. Per ct. per yr. Sinking Fund.	Authority.	Remarks.
Poles					
Iron		4		13	
Wooden		8		13	
& Cross Arms	10–12.5			5	
Rails		5.5		13	
Reservoirs	50–75			2	
"	40–75			6	
"	100			17	
Standpipes	25–30			6	
"		4		14	
"	40			11	
"	30			12	
Storage Batteries	9–11			7	
Switch Boards	10			5	
Ties		7		13	
Track		8–12		9	
"	7–13			7	
Trolley Line	12.5–25			7	
" "		5		13	
Turbines, Water	11–14			7	
Valves	25–35			6	
"	40			11	
Wire, On Poles	25			5	
Wiring of Cars		8		13	

Table showing Prices Paid by the City of St. Louis for Cast-Iron Pipe Delivered at Yards in St. Louis since 1889, per Ton of 2 000 Lb.

Date of Order.	Sizes in Inches, and Quantities in Tons.												Price.
	3	4	6	8	10	12	15	20	30	36	42	48	
——'88													$26.45
2–19–'89			330	75		395							26.33
4– 2–'91						590							27.84
7–28–'91			125			515							26.75
8– 9–'91			1 428	130		910	6			26			26.75
2–10–'92			35			55		1 000	210				19.47
4–25–'92						60					65		24.95
7–30–'92			1 440	40		720							25.48
10–19–'92						5				685			25.48
9–18–'93	10	30	1 400			1 560		2 035		450			19.40
8–21–'94			810			810	10	1 780	3 350	380			19.94
4– 1–'95			8			12			3 307	1 300			19.85
5–23–'95		8	787			55							20.96
9–20–'95								950	5 400				22.47
2– 8–'96	25	75	1 550	15		1 200							24.00
8–12–'96			900			1 450		350					19.64
10–12–'96			5			30		155	2 915	6 905			19.94
6–10–'97			750		6	1 400		1 044					14.57
7–12–'97											53		16.50
9–29–'97				30		70	50	1 200	100				17.84
3–31–'98			575			1 500	15	1 085		25			14.97
7–25–'98			600			1 330		1 405				15	14.08
2–20–'99			650			2 700		350	400				18.80
6–16–'99			600			1 075		1 120		1 305			24.40
4–23–'00			1 000			2 600		2 050					27.49
8–14–'00			12			28				5 350			23.84
5– 4–'01			700			1 620		2 110	820	950			22.93
3– 8–'02			1 145			1 025		2 345	2 770	2 015			25.83
5– 1–'02			830	175	225	550				1 580			28.93
3–30–'03	25												36.25
3–30–'03		15	1 390			1 190	30	1 175	700				32.25
6– 4–'04	70												28.00
6– 4–'04		50	1 140			860		1 160	20	3 200			24.90
5– 1–'05	12												29.45
5– 1–'05			1 160										27.45
5– 1–'05						1 360							26.45
5– 1–'05								375	840	153			25.70
1–29–'06			2 200			2 650		1 650					28.90
9–15–'06			1 350										30.75
9–15–'05						200		1 050					29.80
5–14–'07	24												39.50
5–14–'07			1 430			1 075		1 460		2 161			35.00

DISCUSSION.

MR. ROBERT MOORE. — A large part of the difficulty in making the appraisements of which Mr. Bryan speaks is due to the obscurity of the ordinances under which they are made. As a rule, these ordinances, in speaking of the sum to be arrived at and paid by the municipality, use the word " value," a word which is used loosely in several senses, and which, with rare exceptions, is not properly applicable at all to cases like this.

In economics, as in business, value means " power in exchange "; that is to say, it is the amount in goods or in money for which the article in question will exchange in a free, open and competitive market. But the taking of a water-works plant by a city under the provisions of an ordinance is a forced transfer without competition, to which the rules of the open market do not apply. If the market were really free and open the value of the plant would be determined by its earning power, in other words, the amount upon which it would earn and pay interest would be its value. But this method of valuation is usually by express terms excluded from consideration; and when this is done it is better to avoid the use of the word " value " altogether.

An example of how this may be done and all ambiguity thereby avoided is found in an ordinance of the city of Chicago, dated July 15, 1903, authorizing the Illinois Telephone and Telegraph Company to construct, maintain and operate its tunnels under the streets. Section 6 of this ordinance provides that after twenty years the city may terminate the grant and take over the property, and provides also for a payment to the company in a clause which reads as follows:

> " In case the city council shall decide to terminate the grant and take over the property as aforesaid, then the city shall pay therefor in cash the then cost of duplication, less depreciation, of said tunnel appliances and property, with 5 per cent. addition thereto as compensation for the compulsory sale, but there shall be no allowance for earning power or franchise values."

Under this clause the appraisers will know exactly what to do, and in this respect the ordinance may well serve as a model for other cities.

MR. EDWARD FLAD. — The appraisal of a water-works plant, where the conditions governing the appraisal are not definitely specified in the franchise, or in the instructions of the court, should take into consideration the two elements upon which its value depends. First, the physical value, after making allowance

for depreciation; and second, the net earning capacity, both present and future, which will include the so-called "going" value, and "franchise" value.

In attempting to apply rigid rules to any particular case, the results will often be found to be so far at variance with the generally accepted notion as to the value of the plant that the assumptions must be changed until the results seem fair. This is not a highly scientific method but will often avoid absurd conclusions.

The writer believes that depreciation should be estimated at a fixed annual amount representing the annual charge for a sinking fund sufficient to replace the portion of the work referred to at the end of its assumed life, and not, as Mr. Bryan suggests, by estimating what he calls the "actual value," which takes into account the economical value at the time of the machine or structure. This method is difficult of application, leaves room for considerable difference of opinions, and appears to have no particular advantage. Depreciation as estimated by the sinking fund merely means that so many years of the life of the machine or structure have expired, and that the best modern practice requires an equal annual charge for sinking fund purposes.

There are in any specific case so many modifying conditions which materially affect the value of a plant that it is no wonder that engineers of equal honesty of purpose will arrive at conclusions so far at variance with each other that the layman is apt to imagine that the engineers have been unduly influenced by the interest of their clients.

Mr. Bryan has given a thorough discussion of the various modifying circumstances which must be considered. It would be interesting to have him give in detail the application of his arguments to the particular case which he cites in which he states he acted for "both parties in interest, the city and the company," and the writer suggests that Mr. Bryan add such a statement to his paper.

In making a valuation of a water-works plant, much of the difficulty which one encounters is due to the fact that the franchise either makes no provision for the appraisal or else is not definite in specifying the various elements which shall control.

This leads one to inquire into the shortcomings of the ordinary franchise and the manner in which they can be overcome.

In the past, franchises have been granted in which the element of risk was unnecessarily great. The promoter under-

took to supply water under rates that were fixed, or at least were maximum charges; no limit was placed upon the profits, and the public in general had no means of obtaining information upon the financial operations of the company and was not supposed to have any interest in same.

It seems to the writer that a more mutual responsibility, a removal of part of the element of chance, and a mutual enjoyment of such profits as may arise, would result in less friction between the company and the city, better and more satisfactory service, and would increase the value of water-works securities, which have, in recent years, become almost unsalable. The principal assumptions on which such a water-works franchise should be predicated which have a bearing upon the financial questions involved are as follows:

(1) That the parties investing their money shall be entitled to make an annual profit equal to a definite percentage on the investment, and no more.

(2) That the water rates shall be fixed so as to obtain sufficient revenue to provide for operating and maintaining the works, pay a definite interest on the investment and set aside a fixed amount annually for sinking fund charge.

(3) That the city may, at stated intervals, purchase the works by paying a price which will insure to the investors a return of all of the money invested and interest on same to the time of purchase at the rate agreed upon, and, in addition, a reasonable profit.

The actual rates of interest will, of course, depend upon the size and location of the town and upon the degree of risk involved in any particular case.

As illustrating the application of the above assumptions to a particular case, the writer submits herewith the general terms of a franchise such as, with slight modifications, he recently submitted to a small town in Illinois, in the belief that, as compared with the form of franchise usually granted, the one herewith proposed better protects the interests of both parties, removes in part the element of risk, insures increased value of the securities to be issued, enables the city to participate in the profits, invests the city with a beneficial element of control and establishes a mutually friendly relationship, which cannot but result in the peace of mind of the public which has, in recent years, been prone to unduly villify all public utility corporations.

The system of water works referred to was estimated to cost about $50 000 all complete, ready for operation.

The conditions which it was proposed to incorporate in the franchise are as follows:

(1) Within ninety days after the franchise is granted the company is to submit plans, specifications and estimate of cost for approval of the city council.

(2) When plans, specifications and estimates of cost are approved, the company shall commence work within thirty days and have the plant completed and in operation within twelve months.

(3) Failure to submit satisfactory plans within ninety days, or to have the works completed and in operation within twelve months of approval of plans, specifications and estimates, shall work a forfeiture of the franchise and all the rights and privileges granted therein, if the city council shall so elect.

(4) The city to pay a fixed amount per year, say $4 000, for fire service and for water for public drinking fountains and street sprinkling. A portion of said payment, sufficient to pay 6 per cent. on the bond issue, to be payable directly to the bond holders in semi-annual installments, and a special tax to be levied for its payment.

(5) A schedule of water rates to be provided.

(6) The city to grant the exclusive right to lay pipes in streets, alleys and public places for the purpose of furnishing water.

(7) The company shall have the right to issue bonds equal to the estimated cost of the work, and an equal amount of stock, bonds to bear 6 per cent. interest, payable semi-annually.

(8) All plans for improvements or extensions, unless the cost of same is to be paid out of revenue, must be approved by the city council, and after such approval the company may issue additional bonds equal to the estimated cost of the work and an equal amount of stock.

(9) At the end of each fiscal year the company shall file a sworn statement with the city council of all income and expenditures, showing separately the amounts expended for operation, repairs, improvements and extensions, and for interest, dividends, sinking fund and taxes.

(10) The company shall be allowed to declare dividends equal to 4 per cent. annually, cumulative on all stock issued, all excess earnings to be set aside for sinking fund, invested in bonds of the company or applied to repairs, improvements or extensions.

(11) The city to have the right to purchase the works at the end of the first five years, or at the end of every five years thereafter, upon the payment of an amount as follows:

The face value of all bonds outstanding, with 10 per cent. added thereto, and with all accrued and unpaid interest plus all deferred or unpaid 4 per cent. dividends on stock, as provided for herein.

When the works are so purchased, all of the stock and bonds shall be delivered to the city and it shall assume all current indebtedness and receive all monies on hand at the time of transfer.

(12) It is the intention to fix the water rates so that after paying for all operating expenses and repairs, the company will be able to pay 6 per cent. interest on the bonds, dividends equal to 4 per cent. on the stock, and set aside 2 per cent. annually for the sinking fund. Either party may call for a revision of the existing water rates by notifying the other party in writing between the first and fifteenth of January of any year.

(13) All questions which may arise as to water rates, improvements or extensions, or the estimated cost of same, or as to the purchase price, if the city decides to purchase, shall be decided by mutual agreement of the company and the city council; or failing to so agree, each party shall, within ten days, on the demand of either party, appoint an arbitrator, the two to select a third party; or, failing to so agree upon the third party within twenty days, the said third party to be appointed by the judge of the circuit court of ——— on application of either party. The three parties so appointed shall form a board of arbitration, and the findings of any two of the three arbitrators shall be accepted as final. In every arbitration each of the three arbitrators shall be allowed $25 per day and expenses. The charge per diem and personal expenses of the third arbitrator shall be paid by the party calling for the arbitration. All other expenses of every arbitration shall be divided equally between the two parties. Only such expenses as are approved by at least two of the arbitrators shall be allowed.

(14) The company agrees to use its best endeavors to operate the works in a manner satisfactory to the city; failing so to do the proper remedy is purchase and operation by the city or the resale to some third party.

(15) The franchise to continue in effect until such time as the works are purchased by the city, but not exceeding nine hundred and ninety-nine years.

(16) Any citizen shall have the right to subscribe for the bonds and stock of the company before the work is begun, 40 per cent. of the bonds and stock to be prorated among the subscribers who are citizens of the said city, the balance to be

distributed as may be directed by the party to whom the franchise is granted. For every $1 000 paid in by a subscriber there shall be issued to him $1 000 in bonds and 10 shares of stock of the par value of $100 each, full paid and non-assessable.

In the terms of a franchise, as suggested, the time for completion of certain portions of the work, as well as the amount of payment by the city and the rate of interest allowed, would, of course, be fixed to suit the particular case. Other questions, such as the right to grant an exclusive franchise, or the restraining value of same, if granted; also the legal right to issue bonds and stocks under the conditions stated, would have to be considered.

The writer submits the above for the purpose of starting a discussion on the subject of franchises, believing that the defects in franchises as usually granted are largely responsible for the difficulties encountered in making equitable appraisals when purchase is contemplated by a city.

MR. S. BENT RUSSELL. — In discussing the paper of Mr. Bryan, for the sake of brevity the writer will consider only the case of a water-works plant which has been running some years under a franchise which will not expire for some years. Moreover, he will not attempt to discuss all the points that might arise in such an appraisal, but will only take up a few such points that seem to him of special interest.

Before attempting to decide on a fair purchase price, it is best that we should first consider its value from several different aspects. In order that we may understand the terms we are using, before proceeding with the discussion proper, the following table is given:

A. Fair Purchase Price	B	Physical valuc, or value based on cost of reconstruction. (Mr. Bryan's 5th, nearly.)	M — Cost of reconstruction. N — Age of plant. O — Probable life. P — Market value as second-hand material.
	C	Book value or capital invested as shown by a proper system of book-keeping. (Mr. Bryan's 8th, nearly.)	Q — First cost of plant, real estate, etc. R — Amount charged off for depreciation of plant. S — Profits or losses made by increase or decrease in values of machinery, etc., since the plant was built.
	D	Earning value, or value considered as an investment. (Mr. Bryan's 10th, nearly.)	W — Present net earnings. X — Additional capital required. Y — Future net earnings up to expiration of franchise. Z — Physical value of property at end of franchise.

Items B, C and D in the second column are the respective values obtained by three different points of view. B and C might be grouped together under the head of tangible value. The different values above mentioned are not to be added together, understand, but will each have weight in the final decision. These values are based on the data indicated in the third column of the table. The table will be readily understood in its main points.

Let us now pass to the question of depreciation. We find that item R, the amount charged off for depreciation, is a factor in finding the book value C. What the amount should be is one of the questions raised by Mr. Bryan. Age and probable life enter in. The method generally adopted by engineers is to assume a sinking fund made up of equal annual payments with compound interest, the payments being of such amount that the fund will equal the original cost of the plant at the expiration of its life, less its final salvage value. The writer believes this method to be based on the general practice, where bond issues call for a sinking fund, of requiring equal annual payments to the fund. It is the writer's opinion that, all things considered, this is the best plan in use of arriving at a proper amount to charge off for depreciation.

We see, however, that this method of arriving at depreciation depends on very arbitrary assumptions. Why should we assume equal annual payments to sinking fund? Would it not be more fair to have the annual payments gradually increasing, because the revenue of a water-works plant should gradually increase from year to year? — and it would be easier to have the annual payments more nearly in proportion to the revenue.

If we should adopt a sinking fund made up of gradually increasing annual payments with compound interest, the depreciation at the end of ten years of a thirty-year life would be considerably less than when equal annual payments are assumed as in the usual method. The curve of depreciation on a diagram like Mr. Bryan's would more nearly approach the line which he assumes to represent the actual depreciation.

We will now take up item B of our table called the physical value. The main factors in its determination are M, N and O of the table. Having ascertained the cost of reconstruction at present prices, we must deduct some value depending on the age of plant, having in view its probable life.

There would seem to be no fairer way to do this than by the sinking fund method discussed above. The writer believes,

however, that there is another way that the present physical value of a plant could be arrived at. A steam boiler that has been in service ten years has an approximate market value. Second-hand boilers, engines, etc., could usually be purchased which would be equal in utility to those in the plant under consideration. An estimate might be madc of the cost of obtaining second-hand appurtenances and installing them so as to give a plant equivalent to that under consideration. This method would, of coursc, call for a great deal of judgment and information as to second-hand values. In the writer's opinion, however, this method should receive some consideration from the appraiser in determining the physical value. This valuation is designated as item P of the third column in the table.

Values B and C, if fully worked out with similar assumptions, will givc about the same results. Let us say, for the sake of simplicity, that wc will adopt B as the fair tangible value.

In summing up as to thc tangible value we may say that the present tangible value of a plant is something that cannot be rigorously computed because the depreciation or the influence of agc and probable life cannot be computed. It is probable that no two engineers would decide on the same figure, and it is likely that the same engineer would at different times find different values for the same plant. There is no question, however, that the experienced water-works engineer is the one best fitted to arrive at a faii value.

Coming now to the earning value D, or the value depending upon the financial statement of the operating company, it is well to consider two main factors. First, the financial condition of thc company at the present time, that is, the amount of its receipts compared with the cost of operation, etc.; and second, the probable financial condition at the time of expiration of franchise.

In Novcmber, 1906, the writer made an appraisal of the Marion City Water Works Plant, of Marion, Ohio. In this report he gave a financial table giving the condition in 1906 and the estimated condition in 1915, at which time the franchise expires. The plant was built in 1890. As it is somewhat difficult to determine the basis on which to figure for the future, the writer believes that the method used in the Marion case will be of interest.

In the last five years the street mains had been increased at an average of about 0.9 miles per annum. It was assumed that the mains would continue to increase at the same rate

for the next nine years. This would give in nine years an increase over the mileage of the present system of pipes of 28.6 per cent. It was thought fair to assume that the receipts would in nine years increase more than the mileage of the pipe, and 33 per cent. was taken as the increase. It was thought that the expenses would increase at a less rate than the mileage of pipe, and 25 per cent. increase in expenses was taken. It was assumed that the city bought the plant in 1906 for $220 000 and expended $50 000 at once for additional plant. It was assumed that 8 miles of pipe would be laid in the next nine years, at a cost of $48 500, which was based on the cost of reconstruction of the present pipe system per mile not including force main.

From the above data were found the amount of capital invested in 1915 and the receipts and expenses per annum at that time. The interest was assumed to be 5 per cent. on the investment. It was found that after paying operating expenses and interest there was a balance remaining for renewals or sinking fund, and this balance was found to be considerably larger in 1915 than in 1906. These balances will have to be used first for renewals or sinking fund for renewals, and secondly for another sinking fund if it be necessary. This last fund will be required if the present value of the property is assumed to be greater than the physical or tangible value, because at the end of the franchise only the tangible value may be used.

To make this point clear let us take the case of the Marion plant above referred to. We have assumed $220 000 as the earning value of the property. Now, if the tangible value is only $200 000, at the end of the franchise we ought to get $200 000 for the present plant less the value of the sinking fund for its renewal. This would be a loss of $20 000 in nine years. This would at 3 per cent. call for $1 968.80 per annum.

If the balances left over in the years 1906 to 1915 are sufficient to cover renewals or sinking fund for renewals, and also the amounts required to cover loss on capital ($1 968.80 per annum in the case given above), the value ($220 000) assumed at the start may be considered the earning value of the property.

It is evident that while the earning value of such properties may be computed with some degree of approximation, there is room for wide variations on account of assumed factors.

We have now considered the physical value and the earning value. After deciding on these two valuations we do not add them together by any means. They are simply expressions of the value of the property from two quite different and entirely

independent points of view. If the two values should be equal they may each be taken as the fair purchase price, as by either method of arriving at it the price is fair.

The tangible value (B or C) may be greater than the earning value D or it may be less. From the comparison we may judge whether the property is or is not a financial success. That question having been decided, we must look for guidance as to the final steps necessary to arrive at the fair or appraisal price. In this connection the writer would offer for your consideration the following suggestion:

In arriving at the fair purchase price of such a property as between the present owners and the city, the writer feels that the idea of partnership or joint ownership of the property should be kept in view. When a water works is originally installed, the water company provides the buildings, machinery, pipes, etc., while the city furnishes the streets or right-of-way. We might consider also that the city furnishes the plumbing used in connection with the water works, provides the fire engines and in other ways furnishes its share of the total installation. Considering the city water works as a whole. then, we find that the water company has furnished a part and the city has furnished a part. Therefore, they are joint owners of the concern taken as a whole. It is expected that the water company will, during the life of the franchise, get profits on the operation that will be a return for what it has furnished in the installation. It is expected that the city will get increase in revenue from taxation and advantages in the way of reduced insurance, etc., that will be a return for the part it furnished in the installation. We may say it is assumed at the beginning that both parties will profit by the construction and operation of the water works.

The above-suggested joint ownership argument is strengthened if you believe, as the writer does, that it is the duty of the city giving the franchise to see that the water works is properly managed from its inception and that no money is improperly expended in ill-considered projects or otherwise. The city that has not guarded itself in this way cannot expect to escape the ill effects of its negligence.

Now in applying the above argument at the time of proposed sale we may be able to determine whether or not the water company has received a fair return for what it has furnished, but we cannot so easily determine whether or not the city has received a fair return for what it supplied. If a sale is to be made it would seem to the writer that the aim should be to have each

party receive a proportionate return for what it has provided. Perhaps the fairest way to do this is to divide the profits or loss of operation between the two parties. If the property has been operated to the present time at a loss, the city should be willing to bear part of this loss in acquiring possession of the property. What portion of the loss the city should take is a matter that would be left to the judgment of the deciding party.

We are here reminded of another theory now in use, which is to call this loss, or part of it, the "*going*" *value* of the plant as discussed in Mr. Bryan's paper.

Let us now assume that the partnership theory is to be allowed and that we have found the tangible value to be \$200 000, while the earning value is \$220 000. It would seem not unfair to call the "difference" profit, and divide it in some proportion between the seller and the purchaser. Let us say three fourths should go to the seller, making the purchase price, \$215 000. Had the earning value been only \$180 000, on the same basis the seller should bear three fourths of the loss, making the purchase price \$185 000.

The idea of partnership crudely expressed above is given merely as a suggestion to those who are studying the subject. The writer believes, on the whole, that fixed rules cannot be followed in making appraisals, but he thinks it a great advantage to have the points that come up in appraisals thoroughly discussed by engineers so that greater uniformity of practice will prevail.

Mr. William H. Bryan. — The author fully agrees with Mr. Moore that the word "value" is not the proper term when the transfer is a forced one, as when the city takes over the plant. The term, however, is applicable when the property passes from one private ownership to another, or where the appraisal is made for purposes of rate making or taxation. A clear statement of the method of appraisal, such as that cited by Mr. Moore, would materially assist the average investigation of this character.

Mr. Flad's views as to the impossibility of applying rigid rules strike the author as rather pessimistic. Some problems involving judgment and experience are, of course, involved,—the plant's condition and the probable life of each unit, for instance,—but even here the possibility of serious error is not great. With these assumptions intelligently made, the original cost, cost of duplication, depreciation and present physical value are readily determined with reasonable accuracy. If the assumptions of

probable life are sound, then such value must be somewhere near right. The only remaining factor, then, is the earnings. Will they justify a further allowance for "going" value, determined as stated in the paper, and a still further allowance for franchise value, or are they so small as not even to support the physical value? If so, even that figure must be reduced. Certainly something more logical and tangible than Mr. Flad's "generally accepted notion" as to the value should be insisted upon.

The author agrees with Mr. Flad as to the value of the sinking method of computing depreciation as a general proposition. The method, however, need not, and should not, give results materially at variance with the actual physical value at any intermediate date of appraisal. This he tried to show in the paper. In fact, due consideration of the purchaser's rights necessitates that he receive tangible value for his money, except, of course, where the earnings are large and may properly be considered.

Mr. Flad asks that the author give the detailed application of his arguments to the particular case cited. The figures as to costs, depreciation, sinking fund and present value are stated in the paper. The income was growing fast and had almost reached a point sufficient to pay all operating expense, including interest on present value and an increased sinking fund to cover further depreciation. No net earnings, therefore, existed. There was no demand for reduction of rates, nor were there any other features which affected the general situation. There had been considerable loss during the earlier years of the plant's operation, which, under the author's theory, would have justified some award for "going" value had the earnings warranted. No further consideration, however, could have been given to earnings, even had they existed, as the franchise was about to expire. The author's conclusion, therefore, was that, everything considered, the present actual physical value fairly represented the price at which the company should sell and the city purchase. This figure was accepted by both parties and is to be submitted to a vote of the people in the immediate future.

Mr. Flad's proposed water franchise is a laudable effort to improve existing conditions and to place such investments on a more secure and attractive foundation. The first two of his "principal assumptions" are unobjectionable. The third, however, as shown below, does not seem fair to the purchaser.

The practical application of Mr. Flad's plan will be found to involve some perplexities. It is proposed that the company be

allowed to earn a profit of 4 per cent. above all operating and fixed charges, earnings above that amount to be used for retiring bonds and making repairs, improvements and extensions. Manifestly such a fund could not be used for repairs, as they belong to operating expense. As the price which the city is eventually to pay for the plant includes only the face value of the bonds still outstanding, plus 10 per cent., the retirement of bonds and making of extensions inures wholly to the benefit of the city. The plan, therefore, returns to the city all profits above 4 per cent. In return for this, however, the city must, should it desire to purchase the plant, pay a 10 per cent. margin above the face value of the outstanding bonds as well as all unpaid interest and dividends.

If the plant has not earned interest and dividends, the proposed method of including this shortage in the sale price would result in a high figure being placed on a losing venture. Conversely, where the profits had fully met these items, the selling price would be lower. In the first case, a high price is placed on an unprofitable plant, and in the second a lower price on a profitable plant, results manifestly inconsistent.

Mr. Flad places the 4 per cent. dividend on stock ahead of the sinking fund. This would seem unjustifiable. The keeping up of the plant is a legitimate and necessary item of expense — as much so as labor, fuel, repairs or interest. Therefore, the sinking fund item to cover depreciation must be earned before there can be any net profits available for paying dividends on stock.

Some lawyers would probably find objections to other provisions,— the fact that the stock represents no actual investment, but is allowed to earn 4 per cent., the duration of franchise; its exclusiveness, etc.,— but with these we are not concerned. Certainly such an enterprise is entitled to earn all operating, maintenance and fixed charges. In addition, owing to the uncertainties and risks necessarily attending the business, there should be no objection to a profit up to even 4 per cent., as Mr. Flad suggests. Difficulty will be found, however, in fixing the rates. The plant which Mr. Flad refers to would seem to suit a town of, say, about two thousand five hundred inhabitants. The original rates must be tentative and experimental. Some consideration must be given to rates in neighboring towns similarly situated, if immigration is to be encouraged, factories invited and the supplying of railroads solicited. Low rates are essential to do these things, to build up home consumption and

insure the abandonment of cisterns and wells. Profits come from large numbers of consumers at reasonable rates. To start out with high rates intended to cover all operating expense, fixed charges and 4 per cent. on the stock would be suicidal. Some losses in the earlier years of such plants are usually unavoidable.

The proposed method of purchase does not impress the author as altogether fair. If we assume that the plant has proved as profitable as anticipated, then the stockholders, having earned interest, fixed charges and the 4 per cent. on their stock, all water, have been well repaid. Why should they be given a further profit of 10 per cent.? Why is not every consideration of equity satisfied by repaying their actual investment and having them turn over the plant and the accrued sinking fund?

Suppose, however, that the plant has not been profitable. The purchase by the city being optional, it will consider no higher price than is justified by the earnings. If the company wants to unload and stop its losses, it will have to make a price to suit, regardless of all franchise conditions as to bond issues, profits on same, unpaid interest and dividends, etc.

There is another alternative, of course,—that of continuing the operation of the plant and of asking for a higher rate schedule.

As shown above, however, the possibilities in this direction are limited. Furthermore, higher rates might actually cause a reduction in net income, as causing some customers to go back to cisterns, wells or ponds.

The Illinois idea of readjustment of rates is intended to insure the capitalist a fair return on his investment, but it is equally applicable to prevent excessive profits. In such a case the city would probably demand and secure a lower rate schedule.

Incidentally it may be stated that the cost of duplicating the plant, or its present value, is usually considered more equitable as a basis of transfer than the total investment.

Mr. Russell's analysis is interesting and helpful. An increasing annual sinking fund might be desirable in many cases but there are advantages in uniform payments. The sinking fund plan is in effect an increasing payment on account of the interest earned.

Mr. Russell's suggestion that present values be determined by comparison with quotations on similar second-hand machinery in the open market has at least the merit of novelty. Like all

other methods, however, it will be found difficult of application. Aside from the improbability of finding apparatus of the same type, dimensions, age and condition, the selling price of second-hand machinery follows no known, or unknown, law. In some cases a machine has been so completely rebuilt as to command almost the price of a new machine, and in others, even if in good shape, it is hardly worth more than scrap. Immediate delivery sometimes adds to its selling value also. Even if a few sporadic cases could be found, they would not, in the author's judgment, compare in usefulness to the logical and well-digested use of the sinking fund plan.

The appraisal cited by Mr. Russell raises some important questions. No consideration seems to have been given the "going" value, independent of franchise or earning value. As already stated, there can, in the author's judgment, be no "going" value except when there are net earnings over and above interest and sinking fund charges. If there are such net earnings, then the author would award as "going" value a sum sufficient to cover the legitimate losses of the earlier years plus such sums as can be shown to have actually been spent in building up the business. And this "going" value inheres even when the franchise has expired. If the earnings are more than enough to pay fixed charges on physical plus "going" values, and if these earnings are reasonably sure to continue, then the author would estimate the amount of those earnings during the unexpired period of the franchise and reduce same to their present value. This he would call "franchise" value and add to the sum of the physical and "going" values to arrive at the total fair present value.

The author fears that any attempt to get a city to agree to share possible losses, even if it is also to have the right to share possible profits, is in advance of present-day ideas.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 1, 1908, for publication in a subsequent number of the JOURNAL.]

Association of Engineering Societies.

Vol. XXXIX.	JULY, 1907.	No. 1.

PROCEEDINGS.

Louisiana Engineering Society.

Synopsis of Work done in last Six Months.

The February issue of the Journal published the proceedings of the annual meeting of January 12, which was followed by the annual banquet held at the "Old Hickory."

The regular meeting for February 11 was not held on account of Mardi Gras Eve, at which time even engineers are prone to sacrifice engineering papers to carnival spirit.

The March meeting was held on the 11th of the month. Proposed changes in Constitution and By-laws were submitted for first reading. Mr. A. C. Duval read a very interesting paper entitled, "Remarks on the Flood of 1907," accompanied with two elaborate maps and a chart showing the crest of recent floods and maximum gage heights reached at various stations. An informal discussion followed by a number of the members.

The April meeting was held on the 8th. A proposed outing was suggested and decided upon, and the Outing Committee instructed to provide the ways and means. The formal discussion on "Remarks on the Flood of 1907" was then gone into. Mr. Lawes read his discussion, which proved very instructive. Both Mr. Duval's paper and the discussion by Mr. Lawes will shortly appear in the Journal. The second reading of proposed changes in the Constitution and By-laws followed. Exchange club-house and library privileges were arranged with the Montana Society of Engineers.

The meeting on May 13 was exceptionally well attended. The report of the Committee on Membership and Entertainment, submitted by Mr. S. F. Lewis, chairman, was read, showing that considerable progress had been made in obtaining new members. Mr. W. A. Haller read an interesting paper entitled "Modern Power House Construction," accompanied with numerous drawings and photographs. The Outing Committee, through its chairman, Mr. C. W. Wood, submitted its report, recommending a trip to Bogalusa, La., and the acceptance of a special train and service offered free of charge by the New Orleans Great Northern

R. R. Co., through Mr. J. F. Coleman, engineer. The question of new quarters for the society was taken up and a committee was ordered appointed to look into the matter and to report at the June meeting of the Society. Final action on proposed changes in Constitution and By-laws was taken and the recommendations of the committee adopted.

On June 8 the outing to Bogalusa, La., was taken and proved very enjoyable, the weather being fine and the affair considered a great success. About 150 members and guests had a pleasant and profitable day, visiting that thriving and "built to order" town where some of the greatest engineering work in the South is in progress. The special train pulled out of the N. O. Great Northern depot at 9 A.M. A string orchestra added to the occasion. A stop was made at the North Drawbridge, where Mr. J. C. Haugh, engineer of the N. O. & N. E. R. R. Co., explained the workings of the drawbridge. This bridge is one of two new bridges that were built recently to replace two old ones. They serve to break a six-mile span of trestle work across Lake Pontchartrain. This trestle work was formerly 22 miles long, but has from time to time been filled in, until but six miles remain.

The next stop was made at Slidell, La., where the party visited the Southern Creosoting Works, and saw the process of preparing lumber. A train of cars of untreated lumber was hauled into the huge cylinders, cars and all, and a train of treated lumber hauled out of another cylinder.

Upon arrival at Bogalusa the party went to the immense planing mill, in course of construction, where dinner was served, after which Mr. W. H. Sullivan, of the Great Southern Lumber Company, related some facts in connection with the establishment of the new town and the building of its immense industries. He described fully the big plant, told what had been done and what remained to be done; 600 000 acres of timber land to draw from, enough to keep the mill at full capacity for fifty years. The output will be 600 000 ft. a day, enough to construct from 30 to 40 houses. Fifteen hundred men are now employed in the construction of the mills. So far 18 000 000 ft. of lumber have been used in construction, together with 400 000 brick and 7 000 tons of steel.

Mr. Sullivan then noticed the surprised expressions of the Engineers and the "Missouri" look about them, so he proceeded to show them over the grounds, corroborated what he had said by pointing out the details of the immense undertaking and by explaining the various plants and their workings. After this interesting trip through the place the party returned to the starting point, and President Lawes moved a vote of thanks to Mr. N. G. Pearsoll, manager, and Mr. C. W. Goodyear, Jr., assistant manager of the N. O. Great Northern R. R.; to Mr. W. H. Sullivan, manager of Great Southern Lumber Company; to Mr. Armstrong, of the Southern Creosoting Works, and to Mr. J. C. Haugh, of the N. O. & N. E. R. R. Co., for their splendid entertainment, which helped to make the outing such a success. The train left Bogalusa at 5 P.M. and arrived in New Orleans at 7 with every one aboard enthusiastic over the results of the outing.

The regular meeting held June 10 was well attended. A proposition from Tulane University suggesting (1) that the Society abandon its present quarters and make Tulane University, opposite Audubon Park, its regular meeting place; (2) that the Engineering and University libraries be merged; (3) that the senior class men in the engineering courses at

Tulane be allowed to enter as junior members of the Society without paying the initiation fee; (4) that the Society pay $25 per month toward expenses of heat, light and library operation. The adoption of the above suggestions would have the following advantages: (1) The use of spacious Gibson Hall for meetings; (2) the Tulane Library will become available to members; (3) co-operation and help of engineering faculty.

It was decided to have a letter ballot of the members taken on the above proposition. Mr. W. A. Haller's paper on "Modern Power House Construction" was thoroughly discussed by several of the members and the discussion enjoyed by all. The next meeting of the Society will be in September, the Society voting to adjourn for the summer months of July and August. Appropriate resolutions of thanks to the officials in charge of various industries who entertained the Society on their Bogalusa outing were adopted.

The Secretary announced that the Board of Direction had ordered a letter ballot for 25 applicants to the several grades of membership in the Society.

L. C. DATZ, *Secretary*.

Association of Engineering Societies.

Vol. XXXIX. **AUGUST, 1907.** No. 2.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, June 19, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President E. W. Howe in the chair. Seventy-eight members and visitors present, including ladies.

The record of the last meeting was read and approved.

Messrs. John E. Carty, Ernest R. Kimball, Edward F. Murphy, William F. Mahoney and Henry T. Stiff were elected members of the Society and Mr. John B. Graham an associate of the Society.

The literary exercises were furnished by Mr. Desmond FitzGerald, past president of the Society, who exhibited and described a large number of very beautiful colored lantern slides made from photographs taken by him in his travels in various parts of the world.

Adjourned.

S. E. Tinkham, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXIX. **SEPTEMBER, 1907.** No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, JUNE 5, 1907. — The 636th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, June 5, 1907, at 8.15 o'clock. President Fish presided. Forty-five members and twenty-four visitors were present.

The minutes of the 635th meeting were read and approved.

The following applications were presented: Forest Shepard Lyman, member; Guy Carleton Pierce, associate member.

The following were elected: William B. Ittner, member; Henry Craig Morrison, junior; Hans Schantl, member; Ernest Osgood Sweetser, member.

Mr. West, on behalf of the Western Society of Engineers, extended a very cordial invitation to the Engineers' Club of St. Louis to visit points of engineering interest in and about Chicago. Upon motion of Professor Langsdorf a vote of thanks was extended to the Western Society of Engineers and to their representative, Mr. West, for the courteous invitation.

It was moved by Mr. Toensfeldt that the matter of the date of the proposed trip be referred to the Entertainment Committee. Motion carried.

The paper of the evening, upon the "Present Status of the Producer-Gas Plant in the United States," was presented by Mr. R. H. Fernald. The paper was illustrated by a liberal supply of lantern slides and touched upon the following points:

1. Rapid development of the gas engine.
2. Development of the gas-producer.
3. Tests of the United States Geological Survey.
4. Relative results of steam and producer-gas tests.
5. Views of the manufacturer.
6. Situation to-day regarding various difficulties.
7. Cost of producer-gas installations.
8. Estimated operating costs of producer-gas plants.
9. Views of owners and operators of producer-gas plants.
10. Centralization of power development and distribution.

Written discussion was presented by Mr. M. L. Holman, and oral discussion was participated in by Messrs. Russell, Bryan, E. C. Parker, Richard Phillips, Robert Moore, Palmer, Layman, and Fernald.

Adjourned.

R. H. FERNALD, *Secretary.*

Association of Engineering Societies.

Vol. XXXIX. **OCTOBER, 1907.** No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, September 18, 1907. — The 637th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, September 18, 1907, at 8.15 o'clock. President Fish presided. Thirty-five members and twenty-six visitors were present. The meeting was an open one, and a large number of ladies were among the visitors.

The minutes of the 636th meeting were read and approved. The minutes of the 425th and 426th meetings of the Executive Committee were read.

The records of the trip to Chicago, July 26 and 27, as guests of the Western Society of Engineers, and of the dinner given on July 3 in honor of visiting members and guests of the American Society of Civil Engineers, were read.

The following applications were presented: Henri Rusch (member); Burkett Sale Clayton (member); Lawrence Rudolph Ebert (member); Theodore Barnes Entz (member); Elbridge B. Fulks (member); Henry England Grimm (member); Alfred Lewis Kammerer (member); Edward M. Kurtz (member); William M. Penniman (member); Ejnar Posselt (member); Charles William Sylverius Sammelman (member).

The following were elected: Forest Shepard Lyman (member); Guy Carleton Pierce (associate member, non-resident).

The President called for nominations for the secretaryship, made vacant by the resignation of Prof. R. H. Fernald. Mr. R. S. Colnon nominated Mr. A. S. Langsdorf. Moved by Mr. Richard McCulloch, and duly seconded, that nominations be closed. Motion carried. Moved and carried that the President cast the ballot of the meeting in favor of Mr. Langsdorf. The President thereupon declared the ballot cast and Mr. Langsdorf duly elected.

The paper of the evening upon "A Trip to Egypt" was presented by Mr. Richard McCulloch. The address was illustrated by a large number of lantern slides.

On motion of Mr. Rohwer it was voted to extend the thanks of the Club to Prof. R. H. Fernald for his past services as Secretary.

The members and visitors then adjourned to the reception rooms of the Club, where refreshments were served.

Adjourned.

A. S. Langsdorf, *Secretary.*

St. Louis, October 2, 1907. — The 638th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, October 2, 1907, at 8.15 o'clock. President Fish presided. There were also present twenty-one members and three visitors.

The minutes of the 637th meeting were read and, with a slight correction in the spelling of the name of a candidate for membership, were approved. The minutes of the 427th and 428th meetings of the Executive Committee were read.

The following were elected to full membership: Henri Rusch, Burkett Sale Clayton, Lawrence Rudolph Ebert, Theodore Barnes Entz, Elbridge B. Fulks, Henry England Grimm, Alfred Lewis Kammerer, Edward M. Kurtz, William M. Penniman, Ejnar Posselt, Charles William Sylverius Sammelman.

Applications were read from the following: William S. Dawley, member; Paul A. Fusz (member); Samuel Kauffman (member); John M. Monie (member).

Mr. H. Rohwer, in a written communication, submitted the following resolution:

" In accepting the resignation of Prof. R. H. Fernald as Secretary of the Engineers' Club of St. Louis, the latter, in due recognition of the untiring effort in promoting the welfare of this Club and services rendered, have

"*Resolved*, That the Engineers' Club of St. Louis extend to said Prof. R. H. Fernald its thanks for said labor so performed by him in the interest of this Club; and be it further

"*Resolved*, That the Secretary be instructed to enter this on the books of the Club and furnish said Prof. R. H. Fernald with a copy of same."

On motion, duly seconded, the above resolution was unanimously carried.

The President announced the receipt of a framed photograph, taken on the occasion of the visit of the Club to Chicago, July 26 and 27; the Secretary was instructed to make proper acknowledgment of the same.

The President announced that the expenditure on the occasion of the visit of members and guests of the American Society of Civil Engineers, on July 3, had amounted to $194.10; and that this expenditure, being in excess of the limit prescribed by the by-laws, required the approval of the Club. It was moved by Mr. Layman, and seconded by Mr. Bryan, that the expenditure be approved. Motion carried.

Mr. Richard L. Humphrey read the paper of the evening on " The Work of the Structural Materials Testing Laboratories." The paper was illustrated by a large number of lantern slides, showing details of many of the tests.

An active discussion of the paper was participated in by Messrs. Greensfelder, Bryan, Van Ornum, Toensfeldt, Harting, Fish and R. L. Humphrey.

A motion to extend a vote of thanks to Mr. Humphrey for presenting this paper was unanimously carried.

Adjourned.

A. S. Langsdorf, *Secretary.*

Boston Society of Civil Engineers.

Boston, September 18, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m., President E. W. Howe in the chair. Ninety-one members and visitors present, including ladies.

The record of the last meeting was read and approved.

Mr. John M. Shea was elected a member of the Society.

The President announced the death of Alfred E. Nichols, a member of the Society, who died July 31, 1907, and on motion the President was requested to appoint a committee to prepare a memoir. The President has appointed as that committee Messrs. George A. Nelson and Arthur T. Safford.

Mr. Desmond FitzGerald, for the committee appointed to prepare a memoir of Charles H. Haswell, an honorary member of the Society, presented and read its report.

The Secretary read, in the absence of either member of the committee, a memoir of Frank W. Upham, a member of the Society, prepared by Messrs. Irving T. Farnham and Rowland H. Barnes.

On motion of the Secretary, the thanks of the Society were voted to Mr. John J. Leahy, superintendent of sewers of Boston, for his courtesy in placing the city boat *Cormorant* at the disposal of the Society on the occasion of the excursion down the harbor on August 22.

The thanks of the Society were also voted to Simpson Brothers Corporation for courtesies shown to members this afternoon at the inspection of the Hassam pavement in Cambridge.

Mr. Herman K. Higgins then gave a very interesting informal talk entitled, "Panama from the Human Side." A large number of lantern slides were thrown on the screen, showing not only the work now under way for the excavation of the canal, but the life and scenery at the isthmus.

Mr. F. P. Stearns, with the aid of diagrams, showed the progress that had been made month by month in the amount of material excavated from the canal.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., September 14, 1907. — The meeting of the Society for September, 1907, was held at 225 North Main Street, Room No. 16, at the usual hour. On the arrival of a quorum, Trustee McArthur was selected to preside. The minutes of the May meeting were read and approved. Applications for membership of Messrs. Algie, Kenrick, Eckles, Lincoln, Simons and Schiertz were read, and on approval ballots were ordered. Messrs. N. L. Leonard, Putnam, A. N. Winchell and McCormick by request were placed in the Corresponding Member Class. The chair appointed the following Committee on Nomination of Officers for the coming year: Messrs. Charles W. Goodale, E. W. King and John D. Pope. A communication from President Kinney was read and action thereon postponed till some subsequent meeting.

Adjournment.

Clinton H. Moore, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXIX. NOVEMBER, 1907. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, OCTOBER 16, 1907. — The 639th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, October 16, 1907, at 8.15 o'clock. Vice-President Brenncke presided. There were present thirty-five members and seven visitors.

The minutes of the 638th meeting were read and approved.

Applications for membership from the following-named gentlemen were read: Morton Lewis Byers, William H. Schewe.

The following were elected: Willam S. Dawley (member), Paul A. Fusz (member), John M. Monie (member).

The Secretary read a letter from the Reinforced Concrete Construction Company containing an invitation to the members of the Club to be present at certain tests to be made at Washington University on Friday morning, October 18.

The address of the evening, on "Some Recent Observations of European Railroads," by Mr. Albert T. Perkins, of the Municipal Bridge and Terminal Commission, was then presented. Mr. Perkins spoke informally of his experiences and observations during the summer of 1907 on many of the railroads of Germany, France and England, and illustrated his remarks with numerous slides, showing typical features of track construction, rolling stock and terminal facilities in those countries. In the course of his address Mr. Perkins answered numerous questions asked by members present.

At the conclusion of the address a unanimous vote of thanks was tendered Mr. Perkins for his kindness in thus addressing the Club.

Adjourned.

A. S. LANGSDORF, *Secretary.*

Civil Engineers' Club of Cleveland.

REGULAR MEETING, June 11, 1907, at the Club rooms, called to order at 8 o'clock P.M. by the President. Present: 25 members, 2 visitors.

Minutes, preceding meeting, read and approved.

The tellers, Messrs. Lane and Hanford, reported the election to active membership of Messrs. James Stewart, Eugene R. Woodruff, C. McD.

Townsend, George H. Lapham, Myron B. Vorce, William S. Lougee, Malcolm Hard, William A. Rowe, Gay E. Randall.

The paper of the evening, "The Intake Tunnel and River Shaft of the Detroit Water Works," was read by Mr. James Ritchie.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Regular Meeting, October 8, 1907, at the Club Rooms, called to order at 8.15 p.m. by Vice-President Beahan. Present: 29 members and 2 visitors.

Minutes, preceding meeting, read and approved.

Applications for active membership from the following, approved by the Executive Board, were read: Everett L. Brown, R. Walker Henderson, John P. Iltis, Arthur F. Kwis, Thomas G. Mouat, Paul S. Schmidt, Andrew J. Wenzell, and for transfer from the Montana Society of Horace D. McLeod.

A proposal to confer Honorary Membership upon Mr. William H. Searles, signed by five active members of the Club, was read by the Secretary and referred to the Executive Board.

Mr. William A. Rowe read the paper of the evening, "The Buffalo Air Washer and Humidifier and Some of its Applications to Industrial Purposes."

Luncheon was served after adjournment.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., October 16, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President E. W. Howe in the chair; 72 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Ralph W. Loud, Robert A. Vespers and Frederic J. Wood were elected members of the Society.

The President then introduced Mr. Edward W. DeKnight, of New York, manager of the Hydrex Felt and Engineering Company, who read a paper entitled, "Waterproof Engineering." The paper was illustrated by lantern slides.

A general discussion followed on the waterproofing of concrete and on the necessity of protecting steel embedded in concrete, in which Mr. C. T. Purdy, of New York, and a number of members of the Society took part.

On motion of Mr. Larned, the thanks of the Society were voted to Mr. DeKnight for the very interesting paper which he had read.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., October 12, 1907. — The monthly meeting of the Society for October, 1907, was held at 225 North Main Street, at 8 p.m. Vice-President Arthur H. Wethey presided. Minutes of the last meeting approved as read. Messrs. Algie, Eckles, Kenrick, Lincoln, Schiertz and Simons were elected active members of the Society. The Secretary read an invitation to the Society to hold its next annual meeting at Bozeman, Mont., from the Gallatin Valley Commercial Club. Action deferred.

Adjournment.

Clinton H. Moore, *Secretary.*

Detroit Engineering Society.

Detroit, Mich., October 25, 1907.— The 103d meeting of the Detroit Engineering Society was held in the Employers' Association Hall, Stevens Building, on Friday evening, October 25, 1907, at 8.15 o'clock. President Wheeler presided. Seventy members present.

The minutes of the 102d meeting were read and approved.

The following names were balloted upon and elected: Harlow N. Davock and Waldemar C. Keotz.

The report of the Memorial Committee on the death of William Joshua Phelps was read by Mr. Fales, as follows:

In Memoriam.
william joshua phelps,
Member of Detroit Engineering Society.

The death, on September 3, of Mr. Phelps took out of the world and the profession an earnest man and an accomplished engineer, one who had done something to make life better for all men, and who had made the debt which the world owes to engineers greater.

He was born in Elmwood, Ill., on November 19, 1866; received his collegiate training at Knox. Among Greeks he was a member of the Phi Delta Theta fraternity. In addition to the Detroit Engineering Society, he held membership in the American Institute of Electrical Engineers, the Society of Illuminating Engineers and the American Society for the Advancement of Science.

In the business world he was vice-president of the Phelps Company, and manufactured the "Hylo" lamp, which he invented.

He is credited with being the originator of the turn-down lamp, and the inventor of the motorless flasher, so extensively used in electrical advertising.

In the blaze and brilliance of the myriad twinkling lights which give to our city streets by night the fascination of avenues of romance and legend, his genius still lives and flashes.

It is a pity that a man so richly endowed should leave the world when the potentialities of life were still in the ascendant.

He seemed in a fair way to recover after a radical mastoid operation at the Grace Hospital, but inflammation set in and after a few unconscious days death ensued. His widow, two children, father, mother, brother and sister, survive him.

The final resting place is at Springdale Cemetery, Peoria, Ill.

Signed, F. C. Shenehon,
Bingley R. Fales,
Committee.

Moved by Mr. Fales, supported by Mr. Kales, that the report as read be adopted and published in the ASSOCIATION JOURNAL, and copies sent to members of the family. Carried.

The paper of the evening, upon "Some Recent Experiments in the University of Michigan Ship Model Tank," was presented by Dr. Herbert C. Sadler.

Oral discussion by Mattsson, Shenehon, Lane, Russel, Pessano, etc.

Moved and supported that Dr. Sadler be given a vote of thanks. Carried.

Moved and supported that we adjourn. Carried.

BAMLET KENT, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXXIX. DECEMBER, 1907. No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, NOVEMBER 6, 1907. — The 640th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, November 6, 1907, at 8.15 o'clock. President Fish presided. There were present thirty-eight members and twelve visitors.

The minutes of the 639th meeting were read and approved. The minutes of the 430th meeting of the Executive Committee were read.

The following were elected: Morton Lewis Byers (member), Samuel Kauffman (member), William H. Schewe (member).

Applications were presented from the following: Julius Lilien Jacobs (member), Franklin Dew Hudgins (member), Albert T. Perkins (associate member), Preston Allen Richardson (junior).

This being the first regular meeting in November, the chairman announced that, according to the By-Laws, the election of a Nominating Committee of five members was in order, and nominations for this committee were called for. The following were nominated: E. B. Fay, A. O. Cunningham, S. B. Russell, C. A. Moreno, R H. Phillips, R. Morey, Wm. A. Baehr, R. S. Colnon.

The result of the ballot was as follows:

R. S. Colnon	33
E. B. Fay	33
C. A. Moreno	28
A. O. Cunningham	23
W. A. Baehr	21
R. H. Phillips	21
R. Morey	11
S. B. Russell	10

Messrs. Baehr and Phillips having tied for fifth place, a new ballot was called for, which resulted: R. H. Phillips, 18; W. A. Baehr, 17.

The committee was therefore declared constituted as follows: R. S. Colnon, E. B. Fay, C. A. Moreno, A. O. Cunningham, R. H. Phillips.

Mr. Wm. H. Bryan presented the paper of the evening on "The Appraisal of Water Works and Similar Properties." The paper treated in detail of the various possible methods of estimating the value of such properties with regard to such items as depreciation, "going value," etc.

The paper was discussed at considerable length by Messrs. Robert Moore, Edward Flad, S. Bent Russell, J. R. Cullinane, R. H. Phillips and W. H. Bryan.

The meeting adjourned at 10.40 P.M.

A. S. LANGSDORF, *Secretary*.

St. Louis, November 20, 1907. — The 641st meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, November 20, 1907, at 8.15 o'clock, Mr. Richard McCulloch presiding. There were present about fifty members and visitors.

The minutes of the 640th meeting were read and approved.

The Secretary read a letter from the Reinforced-Concrete Construction Company in which an invitation was extended to the members of the Club to be present at a series of tests on imbedded steel bars and bent bars to be made at the Testing Laboratory of Washington University on November 26, 27, 29 and 30; these tests completing the bonding tests decided upon by the Board of Appeals on July 15, 1907.

The Secretary also read a letter from Mr. Richard L. Humphrey, of the Structural Materials Testing Laboratories, asking for the postponement of the proposed visit of inspection until some future date, to be mutually agreed upon.

The Chairman announced that the next meeting of the Club, on December 4, would be the Annual Meeting.

The following were elected: Julius Lilien Jacobs (member); Franklin Dew Hudgins (member); Albert T. Perkins (associate member); Preston Allen Richardson (junior).

The Nominating Committee presented the following report:

November 20, 1907.

To The Engineers' Club of St. Louis,
St. Louis, Mo.

Gentlemen, — Your Nominating Committee submits herewith the names of the candidates selected for the various offices for the ensuing year.

President — Mr. W. G. Brenneke.
Vice-President — Mr. E. E. Wall.
Secretary and Librarian — Mr. A. S. Langsdorf.
Treasurer — Mr. O. F. Harting.
Directors — Mr. J. F. Hinckley, Mr. W. V. N. Powelson.
Members of the Board of Managers, Association of Engineering Societies — Mr. R. L. Murphy, Mr. O. W. Childs.

Respectfully submitted,
(Signed) R. S. Colnon, *Chairman,*
E. B. Fay,
C. A. Moreno,
A. O. Cunningham,
R. H. Phillips.

The Chairman announced that Mr. Charles F. Müller had died on November 14, 1907.

The paper of the evening on "The New Plant of the Wagner Electric Manufacturing Company" was then presented by Messrs. W. A. Layman and E. B. Fay. Mr. Layman presented the general features of the plant and the policy of the company in planning and constructing the buildings. He stated that five months' occupancy had shown the arrangement to be exceedingly satisfactory and that were the project to be undertaken again, the same plans would be adopted. Mr. E. B. Fay then described the technical features of the design and construction of the buildings, illustrating his statements by numerous lantern slides. Mr. A. H. Timmerman then presented some details of the construction and operation of the power house of the company.

A lively discussion of the paper was participated in by Messrs. W. H. Bryan, Richard McCulloch, Edward Flad, R. H. Phillips, H. H. Humphrey, E. B. Fay, H. C. Toensfeldt, W. Robbins, S. Trepp and A. S. Langsdorf.

In the course of his remarks, Mr. Layman extended an invitation to the members of the Club to visit the plant of the Wagner Company, at a time to be fixed by the officers of the company and the Entertainment Committee of the Club.

Adjourned.

A. S. Langsdorf, *Secretary.*

The Civil Engineers' Club of Cleveland.

Regular Meeting, November 12, 1907, at the Club rooms, called to order by the President at 8 p.m.; present: about 60 members and 25 visitors.

Minutes, preceding meeting, read and approved.

The tellers, Messrs. Horner and Herman, reported the election to active membership of Messrs. Everett L. Brown, R. Walker Henderson, John P. Iltis, Arthur F. Kwis, Thomas G. Mouat, Paul S. Schmidt, Andrew J. Wenzell and for transfer from the Montana Society, Howard D. McLeod.

The same tellers also reported the election to honorary membership of Mr. William H. Searles.

The Secretary read extracts from the minutes of the meeting of the Executive Board, on November 5 last, relating to reports made to the Board: in favor of tendering honorary membership to Professor Benjamin, lately resigned as a member of the Club; to various reports of the Publication Committee, and to a report from the Library Committee relative to a propositon from Case Library for the resuming of former relations subsisting between the Club and the Library, with some important modifications of the former arrangement.

The Secretary, as chairman of a special committee of the Executive Board, with power to report directly to the Club, read the proposition from Case Library and reported that the committee were unanimously in favor of accepting the proposition.

On motion of Mr. Herman the report was received and discussion was deferred until after the reading of the paper of the evening.

Prof. R. H. Fernald, of Case School, then read the paper of the evening, "Producer-Gas Power Plants," illustrated with many lantern slides.

Mr. Swasey followed with remarks eulogizing the work of Professor Fernald along these lines. On motion of a member, a vote of thanks was tendered Professor Fernald.

Discussion of the report of the special Library Committee of the Executive Board followed. On motion of Mr. Osborn, the Secretary was directed to have the proposition of Case Library printed and mailed to the members of the Club for discussion at the December meeting.

On motion of Dr. Howe, the President was requested to appoint a special committee to examine further into the proposition and report to the Club at the December meeting if possible. The President named the following as this committee: Beardsley, Osborn, Herman, Miller and Fuller.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Boston Society of Civil Engineers.

Boston, November 20, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8.10 o'clock p.m.; President E. W. Howe in the chair; thirty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. Julius W. Bugbee and Joseph H. O'Brien were elected members of the Society.

On motion of the Secretary, the thanks of the Society were voted to Admiral Francis T. Bowles, president of the Fore River Ship Building Company, and to his assistant, Mr. J. J. Crain, for courtesies extended to the Society on the occasion of the excursion to the works of that company at Quincy Point, on November 15, 1907.

In the absence of the author, Mr. Stephen Child, the Secretary then read the paper of the evening, entitled, "Civic Centers and the Grouping of Public Buildings, with Suggestions for Boston." The paper was fully illustrated by lantern slides.

Mr. C. Howard Walker, in response to an invitation of the President, spoke of the many admirable opportunities in Boston for the grouping of public buildings, and of the efforts which had been made by the architects to awaken public interest in the matter.

Mr. Sylvester Baxter, secretary of the Metropolitan Improvements Commission, was also introduced and spoke entertainingly of the development of the plan of the late Charles Eliot for the improvement of the Metropolitan district. He also gave an account of the work of the Metropolitan Improvements Commission.

After passing a vote of thanks to Messrs. Walker and Baxter for their discussion of the subject-matter of the evening, the Society adjourned.

S. E. Tinkham, *Secretary.*

Boston, December 18, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., Vice-President Francis W. Dean in the chair; thirty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. William L. Church, Charles C. Doten and Frank M. Gunby were elected members of the Society.

On motion of Mr. F. L. Fuller, the thanks of the Society were voted to Mr. F. H. Keys, general manager of the Robb-Mumford Company, and to Messrs. H. L. Egan and Richard H. Long, for courtesies extended to members of the Society on the occasion of the visit to the boiler shops of the Robb-Mumford Company, and to the new shoe shops of Richard H. Long, at South Framingham, this afternoon.

The Chairman then introduced Mr. W. M. Davis, of Boston, who read a paper entitled, "Economical Lubrication in Large Plants."

The paper was discussed by the Chairman and Messrs. Francis H. Boyer, Ira N. Hollis and Irving E. Moultrop.

The second paper of the evening was presented by Mr. E. G. Bailey, of Boston, entitled, "Furnace Design in Relation to Fuel Economy."

Owing to the lateness of the hour it was voted to continue the discussion of both papers at a meeting to be called after they had been placed in type and distributed to members interested in the subjects.

After passing a vote of thanks to Messrs. Davis and Bailey for their interesting papers which they had presented, the Society adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

A special meeting of the Sanitary Section was held at the Copley Square Hotel, Wednesday evening, May 1, 1907, thirty-eight members being present.

There was a general discussion on the subject of run-off from sewered areas, the methods adopted for securing data and the results accomplished. The discussion was participated in by Messrs. L. M. Hastings, I. T. Farnham, J. H. Kimball, G. A. Carpenter, Leonard Metcalf, R. A. Hale, H. K. Barrows, E. S. Dorr, J. L. Howard and others. Apparatus in use for determining the flow in storm sewers and for recording the intensity of rainfall was described by several of the speakers, and the importance of obtaining accurate data was emphasized by all.

At the conclusion of the discussion, on motion made by Mr. George A. Carpenter, it was voted that a committee of five be appointed by the chair to consider methods for obtaining reliable facts in regard to rainfall and run-off, to endeavor to interest city officials and others in installing apparatus for this purpose and to collect and collate such records as may be obtained.

The Chairman has appointed as members of this committee Messrs. Irving T. Farnham, Lewis M. Hastings, Hector J. Hughes, George A. Carpenter and Harrison P. Eddy.

William S. Johnson, *Clerk.*

A meeting of the Sanitary Section was held at the Boston City Club, Friday evening, November 15, 1907, with sixty-one members present. Prof. C.-E. A. Winslow and Prof. E. B. Phelps read a paper entitled, "Purification of Boston Sewage — Experimental Results and Practical Possibilities." The paper was discussed by Prof. W. T. Sedgwick, Mr. X. H. Goodnough and others. The attendance at the dinner which preceded the meeting was forty-four.

William S. Johnson, *Clerk.*

A meeting of the Sanitary Section was held at the Boston City Club, Wednesday evening, December 4, 1907. Mr. Charles F. Choate, Jr., addressed the Section upon the "Pollution of Waters at Common Law and Under Statutes." The attendance was forty-five.

William S. Johnson, *Clerk.*

Montana Society of Engineers.

Butte, Montana, November 9, 1907. — The regular meeting of the Society for November, 1907, was held at the usual hour, 8 p.m., in the Society Room, 225 North Main Street. Quorum present. Charles H. Bowman was chosen to preside. The minutes of the last meeting were

read and approved. The Committee on Nomination of Officers for next year presented the following names, and the Secretary was instructed to circulate ballots for the same.

President — Archer E. Wheeler, Great Falls.
First Vice-President — Charles H. Bowman, Butte.
Second Vice-President — Frank M. Smith, East Helena.
Secretary and Librarian — Clinton H. Moore, Butte.
Treasurer and Member of Board of Managers of Engineering Societies — Samuel Barker, Jr., Butte.
Trustee — John C. Adams, Butte.

By a vote of the Society, Bozeman, Montana, was chosen as the place for holding the next Annual Meeting of the Society, January 9, 10, 11, 1908. The Secretary was instructed to request President Edward C. Kinney to appoint an Entertaining Committee, and he has made the following selection: Ernest W. King, Clayton M. Thorpe, George M. Lewis.

Mr. John D. Pope was chosen to present the draft of an amendment to the By-Laws. A communication from Mr. Thomas E. Lambert was read by the Secretary.

Adjournment.

Clinton H. Moore, *Secretary.*

Detroit Engineering Society.

Special Meeting, November 26, 1907, Stevens Building. — Mr. Axel Welin, A. I. N. A., Mechanical Engineer, London, England, was introduced by First Vice-President Mattsson, at 8.15 p.m., who presented a paper entitled, "Appliances for Manipulating Lifeboats on Seagoing Vessels."

Discussion followed, by Mr. William Livingstone and Mr. Mattsson, etc.

F. C. Shenehon, *Acting Secretary.*

Detroit, Mich., November 29, 1907. — The 104th meeting of the Detroit Engineering Society was held in the Employers' Association Hall, Stevens Building, on Friday, November 29, 1907, at 8.10 p.m. Vice-President Mattsson presided.

The minutes of 103d meeting were read and approved.

The following names were balloted upon and elected: Wm. H. Dorrance, Geo. L. Grimes, Guy P. Henery, M. S. MacDiarmid and Ira C. Sunderland.

The paper of the evening upon " The Transmission of Heat through Iron Radiators " was presented by Prof. John R. Allen of the University of Michigan.

Oral discussion followed by Weil, Fales, Dunlop, Van Tuyl, Brush, Shenehon, Parke, Allen, etc.

Moved by Mr. Weil that a vote of thanks be given Professor Allen, and that he be requested to prepare his paper for publication in the Association Journal. Carried.

Adjourned, 10.25 p.m.

F. C. Shenehon, *Acting Secretary.*